EXHIBIT 5

Paragon
POLYMER CONSULTANTS

Paragon Polymer Consulting, LLC ♦ csmith@paragonpolymer.com
148 Lugnut Lane, Suite 201, Mooresville, NC 28117 ♦ Phone: (704) 728-5879 ♦ Fax: (704) 663-0073

Report Number 2013115
March 7, 2017

Analysis of NIBCO PEX Plumbing Components

Kimberly Cole, Alan Cole, James Monica, Linda Boyd, Michael McMahon, Ray Sminkey, James Medders, Judy Medders, Robert Peperno, Sarah Peperno, and Kelly McCoy on behalf of themselves and all others similarly situated, v. NIBCO, Inc.; United States District Court for the District of New Jersey; Civil Action No. 13-cv-07871-FLW-TJB

Report Recipients:

Joseph G. Sauder
Matthew D. Schelkopf
Joseph B. Kenney
McCune Wright Arevalo, LLP
555 Lancaster Avenue
Berwyn, PA 19312
Telephone: (610) 200-0580
Email: jgs@mccunewright.com

Bruce D. Greenberg
Kyle A. Shamberg
Lite DePalma Greenberg, LLC
Telephone: (973) 623-3000
Email: bgreenberg@litedepalma.com

Prepared by:

Cynthia L. Smith
Paragon Polymer Consulting, LLC
148 Lugnut Lane, Suite 201
Mooresville, NC 28117
Telephone: (704) 728-5879
Email: csmith@paragonpolymer.com

TABLE OF CONTENTS

BACKGROUND

Kimberly and Alan Cole ("the Coles"), James Monica, Linda Boyd, Michael McMahon, Ray Sminkey, James and Judy Medders ("the Medders"), Robert and Sarah Peperno ("the Perpernos"), and Kelly McCoy have each experienced multiple leaks in components associated with their NIBCO PEX plumbing systems. The incident components have included NIBCO PEX pipe (interchangeably referred to as "tubing"), NIBCO brass insert fittings, and NIBCO stainless steel clamps. These components began leaking as early as one (1) year[1] after installation.

The incident components were warranted by NIBCO, Inc. ("NIBCO") to be free of defects in materials and workmanship for a period ranging from ten (10) to twenty-five (25) years, dependent upon whether the plumbing system utilized only NIBCO products or if other manufacturers' components were used in conjunction with NIBCO plumbing products.[2]

Within the 10-year minimum warranty period, these eleven named Plaintiffs have collectively experienced at least ***39*** leaks in their NIBCO PEX plumbing components. Although the time to the first leak varied from one (1) year to slightly more than six (6) years as shown in Table 1, recurrent leaks occurred with alarming frequency after the initial leak. As of November 30, 2016, the Coles had experienced 19 leaks since their house was built 6.3 years prior.

The incident components associated with these leaks included multiple sizes and colors of NIBCO 1006 PEX tubing, NIBCO brass insert fittings, and NIBCO stainless steel PEX clamps. The incident pipes exhibited a variety of manufacturing dates ranging from February 21, 2007 through May 25, 2011. The pipes were installed by plumbing contractors in Tennessee, New Jersey, Alabama, Texas, Oklahoma, Pennsylvania, and Georgia; and each plumbing system was exposed to potable water (including both well-water and municipally-treated potable water distributed by local water purveyors).

In an effort to determine the root cause of failure for the plumbing components at issue in this case, which leaked between December 2009 and September 2016, Cynthia L. Smith of Paragon Polymer Consulting, LLC personally evaluated the plumbing system at each named Plaintiff's residence (excluding the Monica residence) and personally examined over 110 PEX plumbing assemblies and components that were removed from these homes. The analyzed components included multiple incident pipes, fittings, and stainless steel clamps that had reportedly cracked during service (at least six of which were pipes previously evaluated by NIBCO[3,4,5,6,7] and ultimately deemed not to be

[1] Deposition of Kelly McCoy; page 29
[2] NIBCO-Cole 00022540; NIBCO PEX Warranty
[3] NIBCO-Cole 00083144, Evaluation Response Letter #2012101111 (Kimberly Cole); NIBCO-Cole 00083143, 10/26/12 letter from John McAtee – Confidential
[4] NIBCO-Cole 00084554, Evaluation Response Letter #2013110809 (Linda Boyd) - Confidential
[5] NIBCO-Cole 00084747, Evaluation Response Letter #2014020706 (Michael McMahon)
[6] NIBCO-Cole 000086031, Evaluation Response Letter #2014052805 (Robert Peperno) - Confidential

defective, as shown below in Table 2). Numerous companion pipes, fittings, and clamps that were removed from service in the same installations were inspected for comparison.

Table 1
Leak History for Each Named Plaintiff

Plaintiff	Approximate Installation Date	Approximate Date of 1st Leak	Approximate Time to 1st Leak	Leak Rate
The Coles	May 2009	Dec 2009	1.5 years	19 leaks over 6.75-year span (Dec 2009-Sept 2016)
James Monica	Feb 2011	Jan 2013	2 years	3 leaks over a 6-month span (Jan 2013-July 2013)
Linda Boyd	July 2008 (moved in Dec 2008)	Mar 2013	4.25 years	3 leaks over a 7-month span (March 2013-Oct 2013)
Michael McMahon	2008	Dec 2013*	≤5 years*	6 leaks over a 3-month span (Dec 2013-March 2014)
Ray Sminkey	Dec 2008	Nov 2013	5 years	3 leaks over 3-week span (all in Nov 2013)
The Medders	Feb 2012	Dec 2013	1.8 years	3 leaks over a 6-month span (Dec 2013-June 2014)
The Pepernos	Oct 2007	Dec 2013	6.2 years	4 leaks over a 2.4-year span (Dec 2015-May 2016)
Kelly McCoy	April 2010	~April 2011	~1 year	6 leaks over a 2.7-year span

*Prior leak suspected to have occurred with previous homeowner(s). The McMahons purchased the home in December 2012, and moved in early January 2013.

Evidence suggests that although the Plaintiffs collectively experienced 41 leaks in NIBCO plumbing products, NIBCO paid only one claim on behalf of any named Plaintiff in this case (for damages resulting from a leak at the Medders residence)[8]. The only tasks generally undertaken by NIBCO to evaluate the defective products were visual inspection, pressure testing at 20 psi to 100 psi pressure, and dimensional inspection. With only one exception wherein an independent laboratory was retained to perform a gel content analysis, no effort was made by NIBCO to test for oxidation of the PEX material[9], insufficient stabilization, insufficient cross-linking, contamination in the pipe wall, or residual antioxidant. Further, there is no evidence to indicate that NIBCO researched the manufacturing history to determine if incident pipes exhibited any dimensional non-conformity or other abnormality at the time of manufacture. NIBCO had the ability to perform these tests themselves and/or to have a third-party perform the testing on their behalf, but no such testing was generally performed.

---

[7] NIBCO-Cole 00082821, Evaluation Response Letter #2012071302 (Kelly McCoy) – Confidential; NIBCO-Cole 00082820, Sept 6, 2012 letter from Ken McCoy – Confidential
[8] NIBCO-Cole 00122419, Confidential - Attorney's Eyes Only
[9] NIBCO-Cole 00082824, Internal Inspection Notes for PER 2012071302 (McCoy) - Confidential

Although NIBCO initially determined that James Medders' fittings likely failed due to a manufacturing defect because the fittings were made from a non-specified alloy[10], NIBCO has failed to repair or replace the defective PEX products within the Medders' home or otherwise fulfill its warranty obligations. Similarly, NIBCO has declined to replace Plaintiff Monica's defective NIBCO PEX fittings and clamps.

When NIBCO's internal evaluation reports were compared to corresponding NIBCO evaluation response letters for the incident leaks, multiple inconsistencies were noted (see "Notes," Table 2). For example, NIBCO's Internal Evaluation Summary for a ¾" terra cotta pipe from the McCoy residence specifically states that the sample was found to meet ASTM specifications for outside diameter (OD) and wall thickness.[11] However, the corresponding Evaluation Response Letter claims, "The expanded outside diameter of the tubing would tend to indicate that [the tubing] was overstressed at some point." [12] No evidence of expanded outside diameter was actually identified in this sample.
Similarly, the Evaluation Response Letter for a ¾" red pipe from the Cole residence also alleged that the tubing outer diameter was excessive, thereby providing evidence of thermal expansion or "oxidative water issues.[13] However, NIBCO's internal inspection notes for the same pipe sample stated, "Wall thickness and OD measurements were found to be within ASTM specifications."[14]

In other instances, NIBCO neglected to report key observations that might suggest a manufacturing defect had contributed to the failure. In an evaluation response letter for the McMahon residence,[15] NIBCO noted that "external scratches not attributable to manufacturing processes [were] present at the location of split in tubing," while neglecting to mention that die lines (which are an extrusion defect) were *also* observed at both the interior and exterior surfaces of the tubing, in the vicinity of the incident crack.[16]

Paragon Polymer Consulting performed site inspections at each Plaintiff's residence. During these site inspections, Ms. Smith evaluated and recorded the manner of installation, water chemistry, water temperature, water pressure, and flow rates. In addition, Ms. Smith interviewed each homeowner regarding their leak history and any changes that may have been made to the plumbing system.

---

[10] NIBCO-Cole 00122476, Evaluation Response Letter #2015042310 – Confidential – Attorney's Eyes Only
[11] NIBCO-Cole 00082824, Internal Inspection Notes (PER 2012071302) – Confidential – Subject to Protective Order
[12] NIBCO-Cole 00082821, Evaluation Response Letter 2012071302 (McCoy) – Confidential
[13] NIBCO-Cole 00083144, Evaluation Response Letter 2012101111 (Cole) - Confidential
[14] NIBCO-Cole 00083147, Internal Inspection Notes (PER 2012101111) (Cole) - Confidential
[15] NIBCO-Cole 00084747, Evaluation Response Letter 201402706 (McMahon) - Confidential
[16] NIBCO-Cole 00084750, Internal Inspection Notes (PER 2014020706) (McMahon) - Confidential

Table 2
NIBCO's Evaluation and Response to Plaintiffs' Warranty Claims

Plaintiff	NIBCO PER #	Pipe Size	Pipe Color	NOTE	NIBCO Internal Evaluation/Observations	NIBCO Evaluation Response Letter
Cole	2012101111	¾"	Red	• Evaluation response suggests that denial was based upon gel testing completed by an independent lab, but no evidence of gel testing was found; • Evaluation revealed that Outer Diameter was within spec, but Evaluation Response states "tubing was expanded" • QA records indicate that this pipe was out of round at the time of manufacture, with a maximum Outer Diameter = 0.888" (greater than the reported outer diameter in the incident pipe)	• Brittle split consistent with oxidative failure, • Very minimal crazing observed at 40X after bend-back testing, suggesting minimal surface attack, • Wall thickness and Outer Diameter within spec • ¾" long split along outer wall • Oxidative-type Failure • Product failure analysis report from Jerry James & Associates received with sample	• Tubing not defective • No indication of manufacturing defects • Tubing was expanded ("evidence of thermal expansion or oxidative water issues") • "Application issue" • "The most important test done with NIBCO is the gel test completed by an independent lab. Their findings determine whether we consider the tubing defective or not."
	2012101110	¾"	Red	• Jerry James report was non-destructive only (no gel testing); • Jerry James report notes extrusion lines coaligned with crack; • Jerry James report notes numerous prior examinations of similarly failed NIBCO & CPI PEX pipes; suggestive of a manufacturing defect.	• Consistent with oxidative failure, • Cracking seen at 20X after bend-back testing • Wall thickness and Outer Diameter within spec (0.876-inch) • Product failure analysis report from Jerry James & Associates received with sample	
	2012040513	½"	Red		Product Not Received	N/A
Monica	2013073102	½"		Brass Elbow – this failure and two previously unreported failures were all on the hot side	N/A	N/A
Boyd	2013110809	¾"	Red	• Installed 2008 • 3 leaks: Attic; hot water tank – Cold water side; hot water tank – hot water side • Water tank equipped with PRV • QA records indicate that this pipe was out of round at the time of manufacture, with a maximum Outer Diameter = 0.888" (greater than the reported outer diameter in the incident pipe)	• Discoloration of inner wall • Wall thickness within specification • Outer Diameter is oversized (0.0003-in over specification) • Outer Diameter = 0.882 in • ¾" long split along outer wall • Oxidative-type Failure • "Increase in tubing OD suggests excessive pressure aggravating this attack."	• Tubing not defective • No apparent manufacturing defects • Expanded outside diameter indicates pipe was overstressed • "Application issue"
	2013110102	¾"	Red	• PER notes customer has had 3 failures	N/A	N/A

Table 2, continued
NIBCO's Evaluation and Response to Plaintiffs' Warranty Claims

McMahon	2014020706	¾"	Red	• Pipe with date code 04/03/07-1 FT06-073-1-07 was excessively out-of-round as-manufactured, but NIBCO apparently did not research manufacturing records; • Average Outer Diameter = 0.629", using NIBCO's method of averaging (incorrectly characterized as "oversized") • NIBCO ignored observed die lines, but emphasized scratches; • Pipe incorrectly recorded as ¾" Red (actually ½" terra cotta)	• ½" Terra Cotta pipe • "Outer Diameter is oversized" 0.642" at split, 0.616" +90 • Slight bow in the tube • OD scratch marks, gouge marks, and die lines • ID Die lines • Pressure tested at 20 psi & leaked at split • We observed no manufacturing defects (die lines, porosity, contamination)	• Tubing not defective • No evidence of manufacturing or material defect • "External scratches not attributable to manufacturing processes present at the location of split in tubing." (no mention of die lines) • "Glossy surface and deformation of tubing indicates possible overstress due to clamping in service."
Sminkey	N/A				N/A	N/A
Medders	2015042310	¾"		Forged Brass Elbow	• XRF testing performed – results not stated	• Failure is due to a possible manufacturing defect
Peperno	2014052805	¾"	Red		• Wall thickness within specification • Outer Diameter is oversized (0.0001-in over specification) • Outer Diameter = 0.880 in • Brittle split • Assigned Cause: Oxidative Attack • "Slight expansion of OD may indicate pressure as a contributing factor."	• Tubing not defective • No apparent manufacturing defects • Expanded outside diameter indicates pipe was overstressed at some point
McCoy	2012071302	¾"	Terra Cotta	• Evaluation showed Outer Diameter was within spec, but Response claims "expanded outside diameter"	• CPI DuraPEX • Wall thickness within specification • Outer Diameter within specification • Gel Content within specification (70.4%) • No evidence of UV exposure • Brittle split consistent with oxidative-type failure	• Tubing not defective • No apparent manufacturing defects • Expanded outside diameter indicates pipe was overstressed • Sent to independent 3rd party laboratory for evaluation – lab confirmed that tubing met ASTM standards for PEX tubing • "Application issue"

One of the pipes evaluated by NIBCO, a ¾” red pipe from the Sminkey residence (Paragon Polymer Sample PPX-46) is shown in Figures 1 through 5 below. This sample was clearly cracked through-wall. No pressure testing was performed by Ms. Smith to detect the crack in this pipe or any other, as they were generally readily visible at 5-20X magnification using a stereomicroscope.

Additional stereomicroscope images associated with other incident cracks are attached to this report as a separate appendix, and are discussed in greater detail in the “Visual Inspection and Stereomicroscopy” section of this report.

Figure 1: Incident pipe PPX-46 from the Sminkey residence, shown in the as-received condition. (DSC00142)

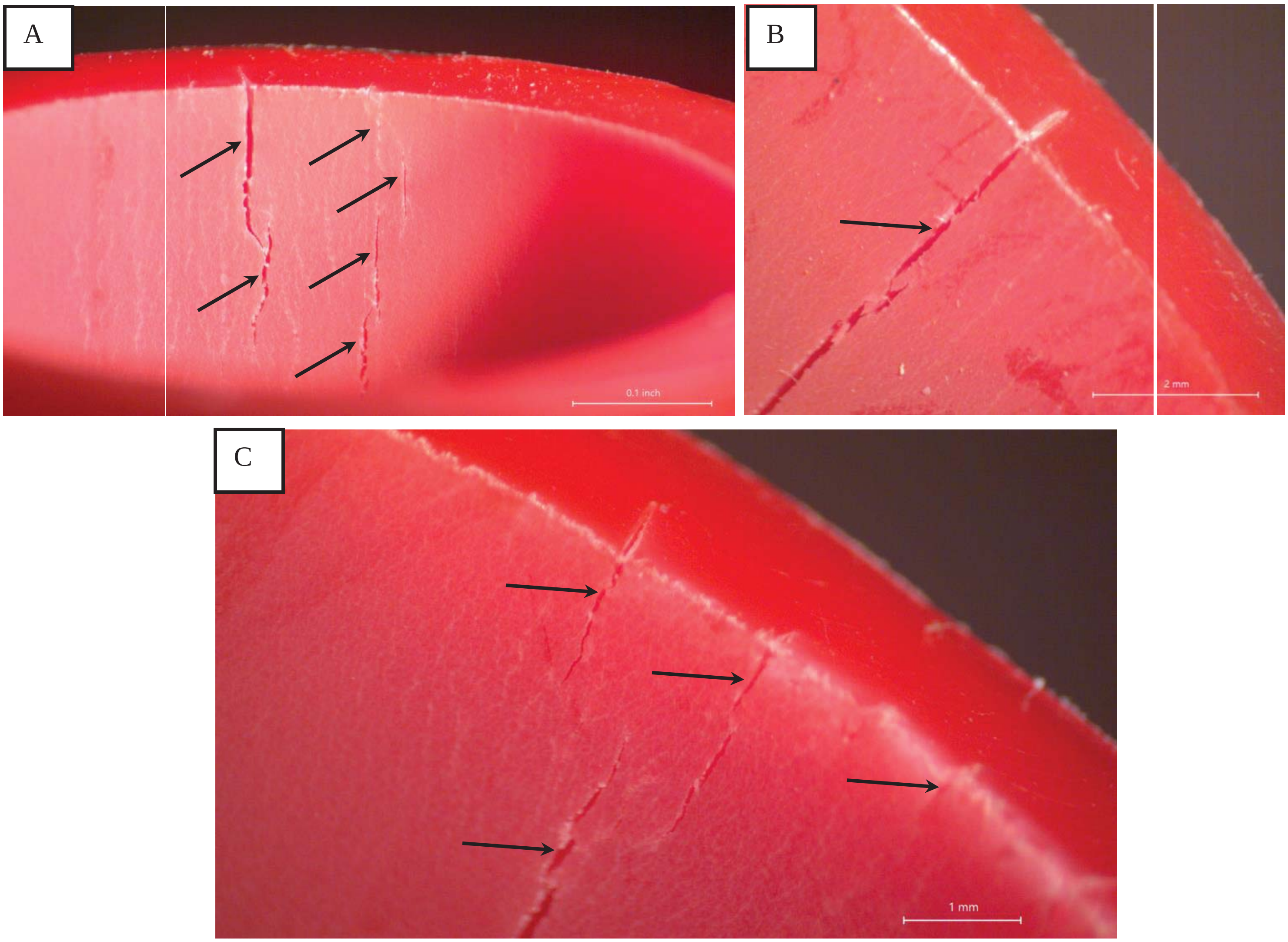


Figure 2: Gaping cracks (arrows) observed at the oxidized interior surface of Sminkey pipe sample PPX-46, shown as viewed using a stereomicroscope.

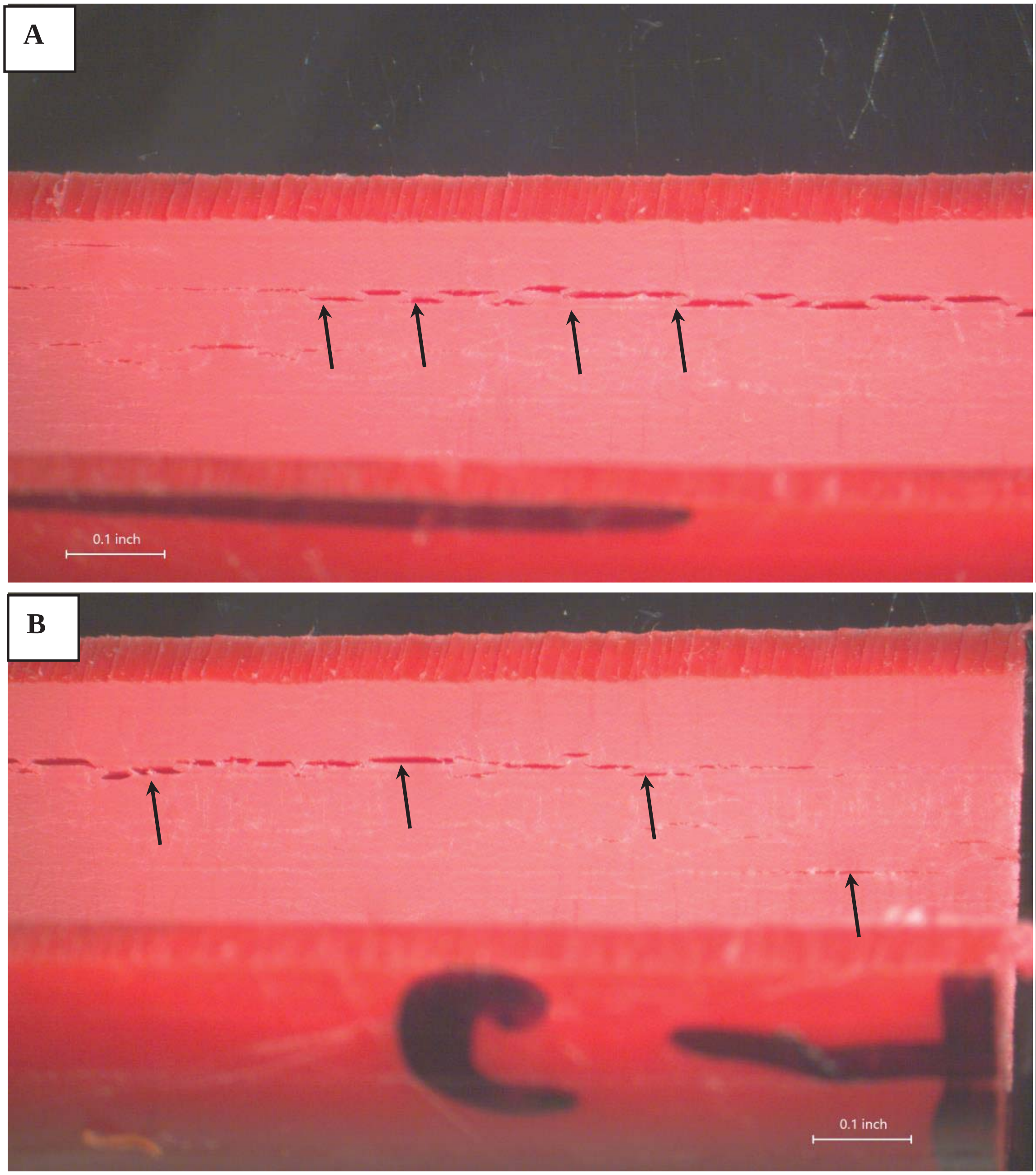


Figure 3: Additional gaping cracks (arrows) visible at the chalky interior surface of Sminkey pipe sample PPX-46, after the pipe was sectioned longitudinally.

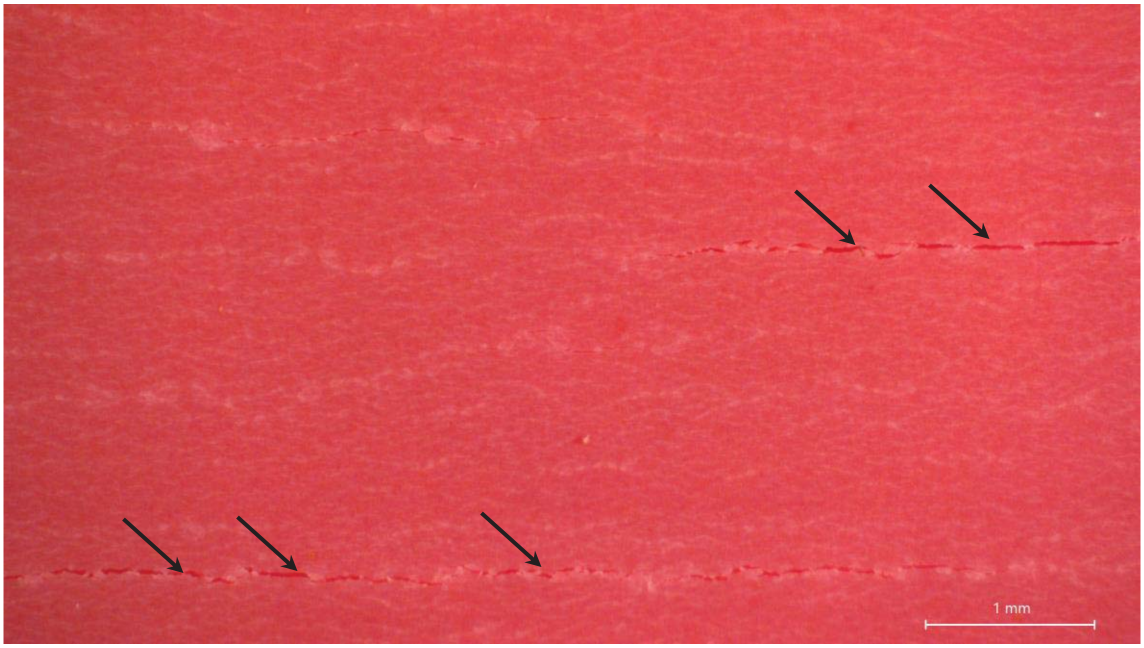


Figure 4: Chalky and crazed interior surface of Sminkey pipe sample PPX-46, shown as viewed using a stereomicroscope. Note that the fine cracks (black arrow) at the interior surface.

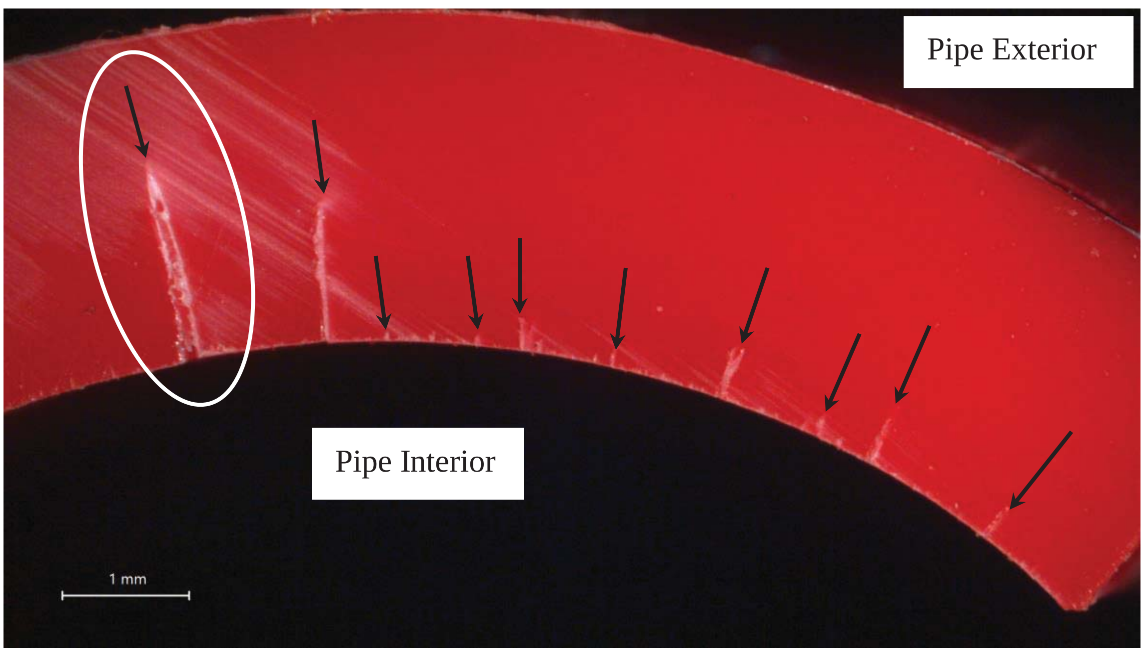


Figure 5: Cross-sectional view of the pipe wall, where approximately 15 partial cracks similar to those identified by arrows could be seen extending 10 to 50% through the wall of the pipe, from the interior surface. The pronounced “v-notch” morphology of the large, encircled crack indicates a high level of residual stress in the polymer material at the interior surface of the pipe. This crack, and other similar cracks, will continue to grow through-wall under hydrostatic pressure.

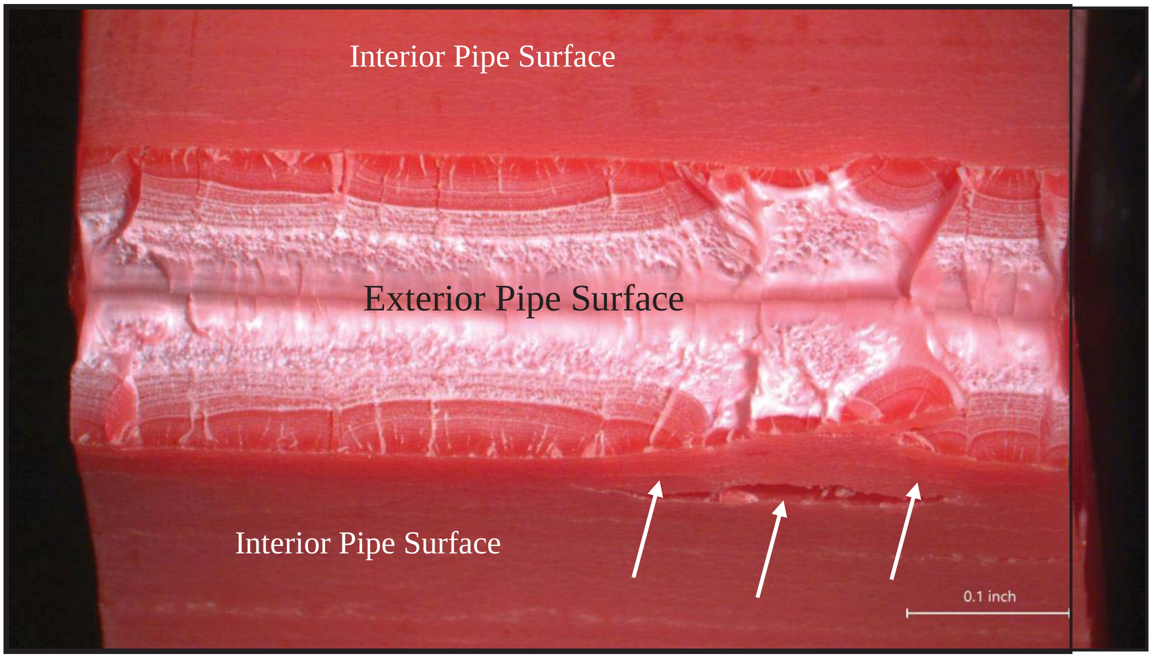


Figure 6: (A) Partial cracks that were mechanically opened to expose the fracture surfaces. These cracks clearly initiated at the interior surface of the pipe and penetrated up to 40% of the pipe wall at this location. Numerous additional crack existed along the full length of Sminkey Sample PPX-46, around the entire pipe circumference.

Additional NIBCO Plumbing Components Analyzed Concurrently

Concurrent with this investigation, Ms. Smith analyzed over 55 plumbing assemblies and/or individual plumbing components (NIBCO PEX pipe, NIBCO brass fittings, and/or NIBCO stainless steel PEX clamps) from three houses associated with a separate class action lawsuit that is currently pending in the United States District Court for the Middle District of Tennessee – Nashville Division (*Meadow v. NIBCO, Inc.*; Case No. 3:15-cv-1124) (herein the "Meadow class action."). In addition, failed pipe samples from four non-named class members were concurrently analyzed.

Although some testing is still pending for the Meadow class action and for this case, the bulk of the testing has been completed. Once the results are finalized, this report may be supplemented and/or amended to incorporate and compare the final test results.

Preliminary results concerning PEX tubing have been virtually identical for the two cases. Additionally, evidence of dezincification corrosion was noted in brass fittings associated with the Meadow class action, although none of the brass fittings at issue in the Meadow case are reported to have leaked during service.

The results of these two concurrent investigations are discussed and compared in this report.

SUMMARY OF CONCLUSIONS

1. The incident pipes from the named Plaintiffs' homes leaked due to through-wall brittle cracking resulting from oxidative degradation and creep rupture of the PEX material.

2. No evidence was found to suggest that improper installation, over-pressurization, excessive temperature, atypical water chemistry, atypical accumulation of surface deposits, UV exposure, excessive bending, misuse, or abuse contributed significantly to failure of the incident pipes.

3. The leaking pipes associated with this class action failed in a virtually identical manner to the other 750+ pieces of failed NIBCO PEX 1006 pipe that Ms. Smith has previously analyzed in other cases across North America.

4. The PEX pipes associated with this case failed in a consistent manner that was virtually identical to the failed PEX pipes from the Meadow class action, which were concurrently analyzed with NIBCO's experts.

5. All NIBCO PEX 1006 pipe is defectively designed and manufactured using a defective process for the intended application, and is likely to fail prematurely in potable water applications.

6. The incident NIBCO brass insert fittings from the Meadow and Cole class actions were all made from yellow brass alloys containing greater than 15% zinc, which renders them vulnerable to premature failure due to dezincification corrosion and stress corrosion cracking in plumbing applications. Such premature failures have occurred in at least two homes from this class action, resulting in a high-volume release of water. Although none of the NIBCO brass fittings associated with the Meadow class action have reportedly leaked yet, evidence of active dezincification corrosion was observed in these fittings.

7. All NIBCO brass insert fittings made from yellow brass alloys containing greater than 15% zinc are defectively designed (due to improper material selection for the intended application) and inherently vulnerable to premature failure due to dezincification corrosion and stress corrosion cracking.

8. The NIBCO stainless steel clamps from the Meadow and Cole class actions were all made from austenitic stainless steel, which renders them vulnerable to premature failure due to stress corrosion cracking in the presence of chlorides.

9. All NIBCO stainless steel clamps for PEX plumbing applications are defectively designed (due to improper material selection for the intended application) and inherently vulnerable to premature failure.

10. NIBCO knew, or should have known, that its PEX 1006 pipe was defectively designed and insufficiently stabilized for the intended application, yet NIBCO made no attempt to warn homeowners about these latent design defects, halt production of the defective product, or recall the defective product.

11. NIBCO knew, or should have known, that its yellow brass PEX fittings containing greater than 15% zinc were defectively designed for the intended application, yet NIBCO made no attempt to warn homeowners about this latent design defect, halt production of the defective product, or recall the defective product.

12. NIBCO knew, or should have known, that its stainless steel PEX clamps were defectively designed for the intended application, yet NIBCO made no attempt to warn homeowners about this latent design defect, halt production of the defective product, or recall the defective product.

QUALIFICATIONS OF EXPERT

The author of this report is Cynthia L. Smith, owner and President of Paragon Polymer Consulting, LLC and Vanguard Material Sciences, LLC. Ms. Smith has over 25 years of experience in fracture interpretation, material characterization, root-cause failure analysis, investigative chemistry, and laboratory testing for a wide range of materials including polymers, metals, elastomers, rubber compounds, adhesives, coatings, and composites. In December 1993, Ms. Smith graduated *magna cum laude* with a degree in Materials Science and Engineering from Arizona State University.

Ms. Smith has extensive knowledge and experience related to the manufacture and performance of high density cross-linked polyethylene (PEX) tubing, brass and plastic plumbing fittings, copper crimp rings, and stainless steel PEX clamps used for potable water and radiant heating applications. From July 2002 through October 2007, Ms. Smith was employed by Uponor North America (one of the world's leading manufacturers of PEX plumbing systems and PEX radiant floor heating systems). In that capacity, Ms. Smith created and managed Uponor's Material Analysis Department, where she tested and analyzed various types of PEX tubing, fittings, and clamps from a variety of tubing manufacturers on a regular basis. While working for Uponor, Ms. Smith was additionally responsible for all root cause failure analyses of field-returned product, and Ms. Smith conducted numerous on-site inspections in individual homes to evaluate the effects of water chemistry, installation, operating temperature, and operating pressure on the performance of PEX tubing. Ms. Smith was also trained by Uponor to install PEX plumbing systems, and periodically participated in training sessions administered to plumbing contractors, participated in engineering design teams to develop new products and materials; was trained by NSF to perform NSF 61 testing; and supported the codes and standards process, supplier quality process, sales and marketing, Return Material Analysis process, and was responsible for the evaluation of field-returned hardware and product testing.

During her tenure at Uponor, Ms. Smith gained considerable experience related to dezincification corrosion, stress corrosion cracking of brass and stainless steel components, and water chemistry testing as it relates to material performance.

Since 2007, Ms. Smith has provided expert consulting in numerous cases involving the failure of PEX plumbing components, and she is a voting member of ASTM International Technical Committee F17 on Plastic Piping Systems.

In 2009, Ms. Smith founded Paragon Polymer Consulting, LLC, a consulting firm dedicated to providing failure analysis, material testing, and investigative chemistry to help organizations improve products and processes, and resolve product liability claims through detailed laboratory analysis. In 2013, Ms. Smith additionally founded Vanguard Material Sciences, LLC, a similarly dedicated laboratory-based testing and consulting firm.

The root-cause analyses of the PEX tubing, brass fittings, and stainless steel clamps at issue in this case fall well within Ms. Smith's range of expertise.

Ms. Smith's educational background, work experience, certifications, and professional affiliations are summarized in her *curriculum vitae*, contained in Appendix 1.

PRIOR WORK EXPERIENCE CONSIDERED

Prior to this investigation and the Meadow class action investigation, Ms. Smith separately inspected and analyzed over 750 additional pieces of similarly-failed NIBCO 1006 PEX tubing, dozens of additional pieces of similarly-failed CPI[17] PEX pipes, and hundreds of similarly failed brass plumbing fittings and stainless steel clamps from a variety of PEX suppliers. These inspections have included, but have not been limited to, products at issue in the lawsuits listed below, and work done during Ms. Smith's employment as Manager of Material Analysis with Uponor North America.

A. *Uponor, Inc. v. Unique Industrial Product Company*
United States District Court for the Southern District of Texas
Civil Action No. 07-2986

B. *Anthony J. Parsons, Adam Stein, and Ellen Stein v. NIBCO, Inc.*
United States District Court, Eastern District of North Carolina
Western Division
Civil Action No.: 5:13-CVS-00744

C. *Kerry Michelle Maloney and Robert R. Ingraham v. Michael James Corbi Individually and d/b/a All-Pro Plumbing, All Pro Plumbing, LLC, and All Pro Plumbing Contractors, LLC*
State of North Carolina
Superior Court Division
Civil Action No.: 12-CVS-01270

D. *Christianson Air Conditioning and Plumbing, LLC v. NIBCO, Inc., MRK Manufacturer's Sales, Inc., and Morrison Supply Company, LLC*
District Court of Travis County, Texas
261st Judicial District
Civil Action No.: D-1-GN-14-000962

E. *H. Leon Comer, Jr. and Judy H. Comer v. NIBCO, Inc., Elite Plumbing, Inc. and Lance B. Pace*
State of South Carolina
Court of Common Pleas of the County of York
Sixteenth Judicial Circuit
Civil Action No.: 2015-CP-46-01851

F. *Constructora Mi Casita, S. de R.L. de C.V. vs. NIBCO, Inc.*
State of Indiana
Indiana Northern District Court
South Bend Office

---

[17] As described in more detail in this report, in May 2006, NIBCO acquired the assets of Consolidated Plumbing Industries ("CPI") and adopted CPI's process for the design and manufacture of 1006 PEX tubing.

In response to Plaintiffs' document production requests in the current class action litigation, NIBCO has produced numerous documents related to at least three of the above-referenced cases:

1. *Parsons v. NIBCO, Inc.*
2. *Christianson Air Conditioning and Plumbing vs. NIBCO, Inc., et al*; and
3. *Constructora Mi Casita, S. de R.L. de C.V. vs. NIBCO, Inc.*

The documents produced by NIBCO include, but are not limited to, Ms. Smith's expert reports[18,19,20,21] and deposition transcripts[22,23] from these prior cases. Ms. Smith's observations, test results, conclusions, and opinions are thoroughly documented through these reports and transcripts, which are incorporated herein by reference.

Nearly all 750+ pipes associated with the above-referenced prior cases (with approximately a dozen or fewer exceptions) leaked due to the combined effects of premature oxidative degradation and stress rupture, in a manner that was virtually identical to the incident pipes at issue in the current class action and in the Meadow class action.

The 750+ pipes from prior cases were evaluated as follows:

A. In 2014, Ms. Smith non-destructively and destructively examined 25 incident pipes that had reportedly leaked during service in the San Antonio area. Destructive testing included stereomicroscopy, scanning electron microscopy, Fourier Transform Infrared Spectrometry, Oxidation Induction Time testing by Differential Scanning Calorimetry, Dimensional Inspection, Energy Dispersive X-ray Spectrometry, and Gel Content Testing on three select samples of failed tubing from three different homes at issue in that case, and two comparison samples of NIBCO PEX tubing that had never been in service.

B. In 2015, as an expert for the plaintiff, Ms. Smith traveled to the Christianson Plumbing facility in Schertz, Texas where she non-destructively examined over 450 additional incident pipes that had reportedly leaked during service, and four coils of NIBCO PEX pipe that had never been placed into service. Based upon the results of the non-destructive examination and service history for the failed pipes, thirty of these pipe samples were selected for additional destructive testing, including sectioning, photo-documentation, detailed stereomicroscopy, Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy, Energy Dispersive X-ray Spectroscopy, Dimensional Inspection, and Gel Content Analysis per ASTM D2765. NIBCO's representatives witnessed destructive testing of those samples.

---

18 NIBCO-Meadows 00143134 – Expert Report of Cynthia Smith (Parsons)
19 NIBCO-Meadows 00128077 – Expert Report of Cynthia Smith (Christianson)
20 NIBCO-Meadows 00142767 – Preliminary Expert Report of Cynthia Smith (Mi Casita)
21 NIBCO-Cole 00096989 – Technical Report of Cynthia Smith (Hanahan, SC)
22 NIBCO-Cole 00098275 – Deposition Transcript of Cynthia Smith (Parsons)
23 NIBCO-Cole 00128006 – Deposition Transcript of Cynthia Smith (Christianson)

Ms. Smith also selected approximately 20 homes in the San Antonio area for detailed water chemistry analysis in an effort to evaluate the composition of the water and determine if the water chemistry might be contributing to failure of the NIBCO PEX pipes. NIBCO was provided a copy of those water chemistry results.

The manufacturer's print string on the four coils of never-installed NIBCO PEX tubing that Ms. Smith evaluated in 2015 on behalf of Christianson Plumbing revealed the following:

- two pipes were labeled "1006 PEX," indicating that they were manufactured from the same PEX formulation as the incident 1006 PEX pipe that is at issue in this case, using the same processing parameters.[24]
- the other two coils of never-installed pipe were made from NIBCO's 3308 PEX formulation[25] (a re-designed formulation that NIBCO introduced in 2012 primarily to provide improved resistance to oxidative brittle failure in chlorinated water).

The prior analyses of these four coils of never-installed pipe are described in detail in Ms. Smith's reports from the *Christianson* matter, which were produced by NIBCO in this case.[26,27] Since the results are relevant to this case, they are incorporated herein by reference and are discussed in greater detail below.

C. In October 2015, as part of her work in the *Christianson* matter, Ms. Smith traveled to Aurora, IL and spent approximately two weeks at NIBCO's experts' laboratory facility, jointly testing nearly 100 pipes that had failed during service in and around San Antonio, Texas. NIBCO received copies of all data related to that joint inspection in October 2015.

D. In May 2016, as part of expert work as the plaintiffs' expert in the *Mi Casita* matter, Ms. Smith traveled to Baja Mexico to examine 230 incident NIBCO PEX pipes that had reportedly leaked during service, and to inspect 20 plumbing installations associated with those failures. NIBCO had previously inspected the same pipe samples and similar installations within the same condominium community.

Ms. Smith intends to rely upon the full breadth of her experience in the PEX industry, her educational training, and the full breadth of her career in failure analysis. She also intends to rely upon any prior test results, data, videos, or photos described in any or all reports that have been produced by NIBCO (including reports that were authored by NIBCO's experts and other laboratories).

---

[24] NIBCO-Cole 00128106 (photos comparing installed to never-installed pipe)
[25] NIBCO-Cole 00128077 at 00128106 – Confidential – Paragon Polymer Consulting Report
[26] NIBCO-Meadows 00142959 - Confidential - Vanguard Material Sciences Report dated June 5, 2014
[27] NIBCO-Cole 00128077 – Confidential – Paragon Polymer Consulting Report

FACTS, DATA, AND DOCUMENTS CONSIDERED

- EXOVA-MEADOW-000001 to 000113
- JANA-000001 to 002470
- NIBCO-MEADOWS 00000001 to 00149386
- NIBCO-COLE 00000001 to 00138036
- NSF 00001 to 00099
- PLMCLAUGHLIN-00001 to 00043
- PLMEADOW-00001 to 00073
- PLPLISKO-0001 to 0079
- SMI 012017 000001 to 001876
- SUNBELT 000001 to 000529
- Total-Meadow 000001 to 002271
- TrueHomes-Subp 000001 to 000082
- Deposition Transcripts:
    - NIBCO 30(b)(6) in the Cole class action (Thomas Coe, Corporate Representative), June 21, 2016
    - Mark Clark, October 11, 2016
    - Earl Sexton, October 11, 2016
    - Kenneth McCoy, October 12, 2016
    - James Medders, November 16, 2016
    - Judy Medders, November 16, 2016
    - Michael McMahon, November 17, 2016
    - James Monica, November 29, 2016
    - Ray Sminkey, December 20, 2016
    - James Grant Dow, December 7, 2016
    - Deborah Premus, December 14, 2016
    - NIBCO 30(b)(6) in this case (Thomas Coe, Corporate Representative), January 5, 2017
    - Susan Plisko, January 10, 2017
    - Linda Boyd, January 11, 2017
    - Chad Meadow, January 12, 2017
    - Kelly McCoy, January 16, 2017
    - Randy Doering, January 18, 2017
    - Robert Peperno, January 23, 2017
    - Sarah Peperno, January 23, 2017
    - Kenneth McLaughlin, January 26, 2017
    - Scott Perry, February 1, 2017
    - David Bobo, February 2, 2017
    - Alan Cole, February 13, 2017
    - Kimberly Cole, February 13, 2017
- Photos, lab data, site inspection notes
- PACE Analytical reports for water chemistry testing
- Chemical Analysis reports from IMR Test Labs
- Metallography images collected by Element Materials Technology Laboratory

- Leak summaries provided by attorneys
- ASTM standards as referenced within this report
- Several thousand photos and microscope images have been taken in support of this project, and numerous data files (Fourier Transform Infrared Spectra, Oxidation Induction Time thermograms, EDS spectra, etc.). Although this report contains a few illustrative photographs and sample data files, Ms. Smith considers all photographs and data files relating to this matter to be a part of this report, whether specifically presented or not.
- Published Literature documented in Appendix 2.

PROJECT SCOPE

Ms. Smith was retained by McCune Wright Arevalo, LLP and Lite DePalma Greenberg, LLC on behalf of the Plaintiffs, to inspect the named Plaintiffs' incident PEX plumbing systems; to review information currently available regarding the failure histories in the Plaintiffs' homes; to investigate the operating environment, design history, manufacturing/distribution history, certification history, marketing history, installation history, and service conditions associated with the incident plumbing systems; and to render an unbiased expert opinion regarding the root cause(s) of failure.

Ms. Smith's fee schedule is contained in Appendix 3, and a list of depositions and/or trials that Ms. Smith has testified in since 2007 are contained in Appendix 4.

SUMMARY OF FINDINGS

i. NIBCO's PEX 1006 Pipe is Defectively Designed and Defectively Manufactured

The above-referenced leaks reportedly occurred in both hot and cold water residential plumbing systems that were municipally treated with chlorine. Chlorine and chloramine, which are commonly used to disinfect potable water in the United States, are known to cause aggressive oxidation and cracking in PEX pipe. For this reason, PEX manufacturers design their pipe formulations and manufacturing processes to maximize the performance of their finished products in hot chlorinated water (since chlorine is known to be more aggressive to PEX than chloramine), while simultaneously balancing the need to utilize a resin that can be processed consistently and cost-effectively, without degrading the resin or introducing processing defects (bubbles, dimples, cracks, excessive shear stress, oxidized polymer inclusions, surface discontinuities, etc.). The manufacturer must then decide what additional additives will be blended into the resin to protect the material from oxidation and embrittlement during manufacturing and service.

NIBCO's PEX 1006 pipes are constructed from a high-density polyethylene (HDPE) resin. As noted previously, HDPE is known to fail in potable water unless certain steps are taken to strengthen the pipe and to protect the polymer material from oxidation and creep. The following design considerations are critical to the ultimate performance of the product: (1) resin selection (not all HDPE resins are created equally, and most PEX manufacturers opt for an ultra-high molecular weight polyethylene resin); (2) adequate stabilization of the material through the addition and uniform distribution of antioxidant(s), UV inhibitors, etc. (3) adequate cross-linking of the HDPE material to improve strength and crack resistance, (4) exercising care during manufacturing to avoid the consumption or degradation of stabilizers to ensure that the HDPE material is not de-stabilized or oxidized during extrusion and cross-linking, and (5) optimizing processing parameters to minimize thermal gradients in the pipe wall, which increase residual stress in the PEX material (thereby increasing susceptibility to cracking). Collectively, these measures form the design of the PEX pipe, and ultimately determine how the pipe will perform in a potable water environment.

"Crosslinking" is a process by which long chain molecules are "tied" together through the creation of chemical bonds to help further improve the strength and crack-resistance of the polymer. There are three primary methods currently available for cross-linking PEX tubing: PEX-a, PEX-b, and PEX-c. PEX-a uses peroxide to catalyze the cross-linking process. PEX-b uses siloxane followed by moisture curing to achieve cross-linking, and PEX-c (the process utilized by NIBCO) relies upon irradiation with a high-energy electron beam to generate cross-linked bonds in the PEX material.

To the extent permitted by applicable regulations and industry standards, each manufacturer chooses what resin it will use, what additional stabilizers it will add, what pigments it will (or will not) incorporate to color the pipe, what method of cross-linking it will employ, to what extent its material must be cross-linked to optimize the

performance of the finished product, and what processing parameters will be required to make quality pipe (extrusion temperature, extrusion pressure, line speed, etc.). There are many decisions to be made when designing a PEX manufacturing process, and each and every one of those decisions can positively or negatively impact the ultimate performance of the pipe.

Pipes that are excessively cross-linked may not have sufficient flexibility for the intended application, while pipes that are not sufficiently cross-linked may not exhibit adequate resistance to cracking. Pipes with insufficient levels of antioxidants and/or with excessive levels of transition-metal oxide pigments (like iron oxide or aluminum oxide) may experience embrittlement during service and develop recurrent pin-hole leaks, like the pipes at issue in this case.

These decisions and the defined-manufacturing process that ultimately emerges from them constitute the "manufacturing design" of the pipe. The "manufacturing design" of NIBCO PEX 1006 pipe was defective, in that the materials and manufacturing process were inadequately designed to produce pipe with suitable resistance to oxidative degradation and premature failure in the intended service environment.

ii. Documentary Evidence Demonstrating that NIBCO's 1006 PEX Tubing is Defectively Designed

Documentation produced by NIBCO teaches that NIBCO first entered the PEX market in 2005 with the introduction of the "NEXT-Pure" PEX potable water system.[28] From 2004 through 2006, NIBCO's NEXT-Pure PEX pipe was manufactured by CPI on behalf of NIBCO.[29] NIBCO marketed, distributed, and warranted the NEXT-Pure PEX pipe. This practice continued until May 15, 2006, when NIBCO acquired the assets of CPI[30] and began to manufacture its own PEX tubing.

NIBCO ventured into this acquisition with less than two (2) years of prior experience in the PEX industry; none of which included the actual *manufacture* of PEX tubing. Yet, marketing materials published by NIBCO commonly claimed the following:

- "When you choose the NIBCO brand, there are no surprises. You get a system that works exactly like you expect – every time!" [31]
- "NIBCO Dura-PEX…you're not just buying a name, you're buying…industry knowledge, ***100+ years of experience***, …and best-in-class service." [32]

---

[28] NIBCO-Cole 00010026, "A History of Leadership…. The NIBCO Advantage."; Contractor Magazine; "NIBCO buys Consolidated Plumbing Industries;" http://contractormag.com/plumbing/cm_newsarticle_909; June 1,2006
[29] NIBCO 30(b)(6) Deposition (Tom Coe, Corporate Representative), 1/5/17 at 85:11-86:2.
[30] Contractor Magazine; "NIBCO buys Consolidated Plumbing Industries;" http://contractormag.com/plumbing/cm_newsarticle_909; June 1,2006
[31] NIBCO-Meadows 00001181
[32] NIBCO-Meadows 00001181

Following the acquisition of CPI's assets, NIBCO began to manufacture 1006 PEX tubing itself, utilizing the same formulation, the same manufacturing processes, the same equipment, the same facility, the same QA/QC practices, and many of the same employees that had previously been utilized by CPI. Through at least December 2006 and likely beyond, NIBCO even continued to label its PEX pipe with the CPI logo. [33]

Over time, NIBCO identified that the 1006 PEX formulation was unable to provide adequate resistance to hot chlorinated water. This placed NIBCO in jeopardy of losing its product listing with third-party certifier NSF because the pipe could not consistently pass the ASTM F2023 chlorine resistance testing required by ASTM F876.

NIBCO subsequently launched a redesign effort in conjunction with Jana Laboratories, Inc. in an effort to develop a reformulated pipe with markedly improved resistance to oxidative degradation. Internal documentation related to an executive-level review of the PEX development strategy[34] explicitly states that this reformulation effort was initiated because NIBCO was at significant risk of losing the [then] current 3rd Party Certification due to variability in the 1006 product's performance when compared to industry chlorine resistance standard & code requirements.[35] This same document goes on to state, "Without 3rd Party Certification, NIBCO [would] not be able to manufacture and sell the [then] current PEX pipe in the Potable Water Market."[36]

A confidential internal document prepared by NIBCO in 2009 (prior to the reformulation effort) acknowledged that chlorine acts as a catalyst for oxidation, eventually causing PEX pipes to crack and fail; and that elevated water temperatures and pressures dramatically increase the oxidation reaction (reducing the PEX pipe life expectancy).[37]

NIBCO was not able to achieve its goal of developing a PEX-c product suitable for 100% recirculation in hot chlorinated water. However, in 2012, NIBCO did introduce a 3308 PEX pipe with improved chlorine resistance. Rather than halting production of the defectively-designed and insufficiently-stabilized 1006 PEX pipe in 2009 until a more robust alternative could be introduced, or alternatively issuing a recall for the defective pipe once the improved formulation went into production in 2012, NIBCO opted for a quiet, rolling change-over that would allow it to use up all remaining defective 1006 resin and inventory associated with the deficient 1006 PEX tubing.[38]

After NIBCO's improved 3308 PEX formulation became available, NIBCO continued to sell the defectively designed and insufficiently stabilized 1006 PEX tubing, even

---

[33] NIBCO-Cole 00062074, NIBCO Standard Operating Procedure for Print String Inspection (SOP PQ-1015, Revision: A; Effective: 9/14/06 through 8/20/2008
[34] NIBCO-Cole 00015405-00015423 – CONFIDENTIAL
[35] NIBCO-Cole 00015405 at 00015407 – CONFIDENTIAL, ATTORNEYS' EYES ONLY
[36] NIBCO-Cole 00015405 at 00015407 – CONFIDENTIAL, ATTORNEYS' EYES ONLY
[37] NIBCO-Cole 00015405-00015423 – CONFIDENTIAL
[38] NIBCO-Cole 00134259 at 00134264 – CONFIDENTIAL; Deposition of David Bobo, 2/2/17 at 200:2-6

knowing that this product did not consistently conform to the requirements of ASTM F876 and that it would likely fail prematurely in contact with hot chlorinated water.

Despite that knowledge, NIBCO has consistently denied warranty claims related to recurrent leaks in its 1006 PEX pipes (Next-Pure, DuraPEX, and NIBCO PEX).[39]

Jana Laboratories, Inc. performed extensive testing on behalf of NIBCO from 2006 through at least 2013. Many of the reports prepared by Jana consistently demonstrated that NIBCO PEX 1006 pipe exhibits almost no resistance to oxidation (particularly at the interior surface of the pipe), and that the pipe exhibits very non-uniform resistance to oxidation around the pipe circumference. Within the wall of the pipe, significant variability also exists from the interior surface to the exterior surface at any given circumferential location. ASTM F876, which NIBCO's product was required to conform to, explicitly states that the pipe must be "homogeneous throughout…and as uniform and commercially practicable in color, opacity, density, and other physical properties."[40]

In one report,[41] Jana Laboratories, Inc. documented oxidation-induction-time testing performed on NIBCO's existing PEX 1006 pipe formulation and other competitive products. Jana Laboratory Figures 1 and 2 from that report are shown below.

These figures show OIT distribution patterns that are remarkably similar to the OIT patterns observed in the failed PEX pipes at issue in this class action and the Meadow class action. All NIBCO PEX 1006 pipe would be expected to exhibit non-uniform stabilization of the PEX material with very limited resistance to oxidation, particularly at the interior surface of the pipe, similar to the relative distributions shown below.

[39] NIBCO-Cole 00024659 – ATTORNEYS' EYES ONLY
[40] ASTM F876-07 – Standard Specification for Cross-linked Polyethylene Tubing, ASTM International, 100 Barr Harbor Drive, West Conshohoken, PA 19428.
[41] NIBCO-Cole 00016181 at 00016187 – CONFIDENTIAL, ATTORNEYS EYES ONLY

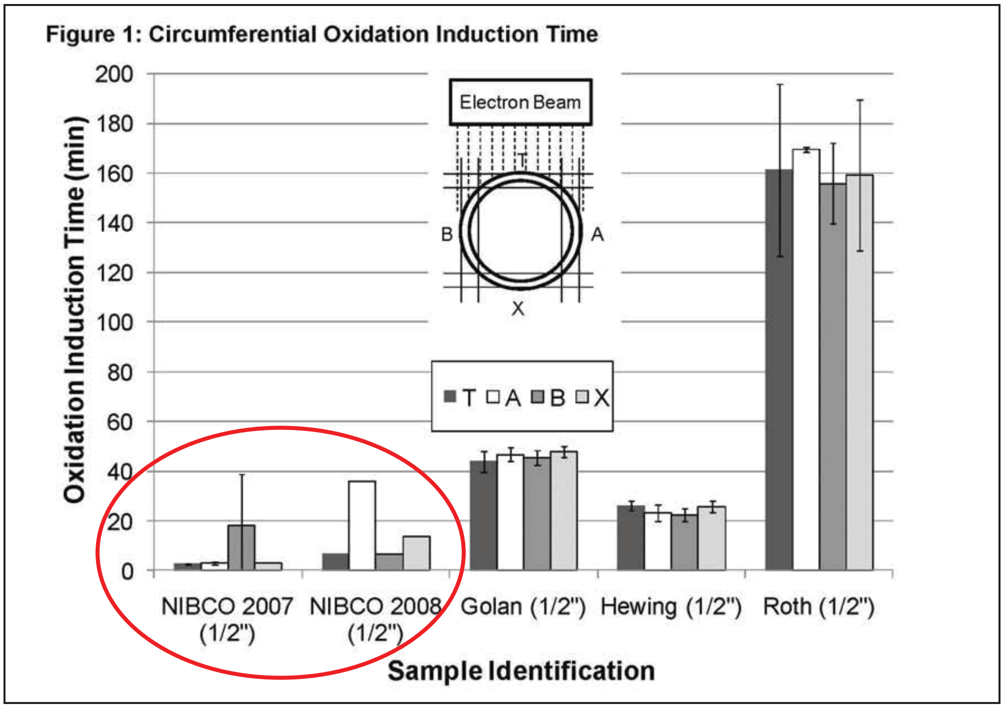


Figure 1: Circumferential Oxidation Induction Time
Oxidation Induction Time (min)
200
180
160
140
120
100
80
60
40
20
0
Electron Beam
T
B
A
X
T A B X
NIBCO 2007 (1/2")
NIBCO 2008 (1/2")
Golan (1/2")
Hewing (1/2")
Roth (1/2")
Sample Identification

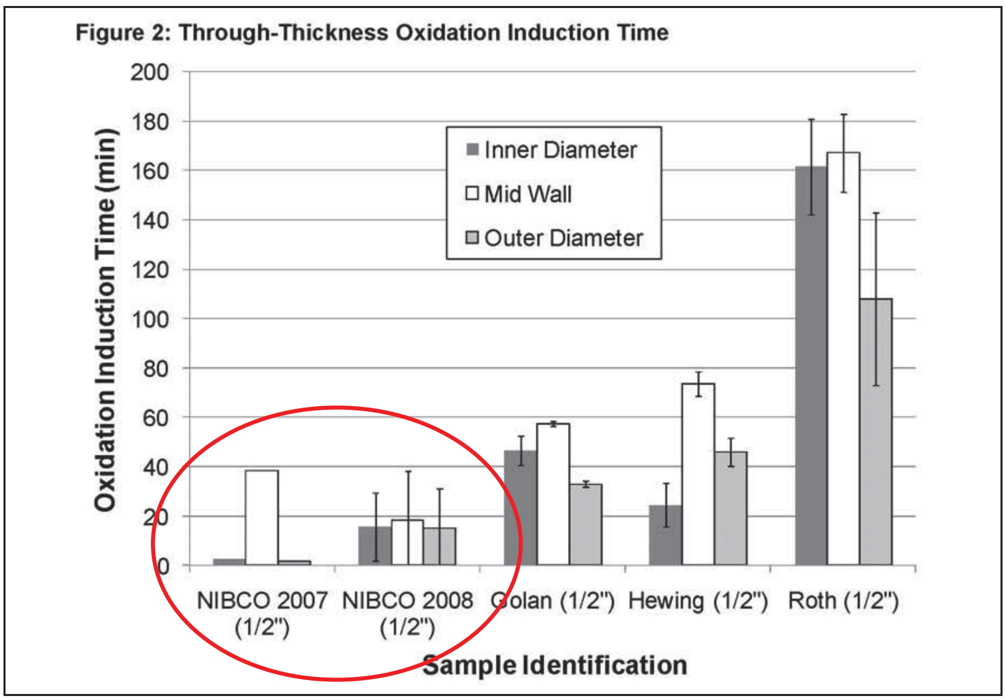


Figure 2: Through-Thickness Oxidation Induction Time
Oxidation Induction Time (min)
200
180
160
140
120
100
80
60
40
20
0
Inner Diameter
Mid Wall
Outer Diameter
NIBCO 2007 (1/2")
NIBCO 2008 (1/2")
Golan (1/2")
Hewing (1/2")
Roth (1/2")
Sample Identification

In analyzing these charts, Jana Laboratories, Inc. wrote:

> Based on the above, the current NIBCO formulation appears similar to competitive samples with respect to both the bulk and circumferential crosslink level, albeit with slightly greater variation for the NIBCO formulation. The OIT and, by inference, the residual stabilizer level for the current NIBCO formulation displays much greater variation than the competitive samples.
>
> Ultimately, it was concluded that the circumferential variation in crosslinking is, in fact, a characteristic of the electron irradiation process and most likely cannot be eliminated and did not warrant, at this time, process changes to reduce the variation. It was also concluded that the current NIBCO product formulation has a characteristically different response to the irradiation process resulting in the highly variable OIT values.

This Jana Laboratories, Inc. report was dated October 30, 2009, and yet NIBCO continued selling the defective PEX 1006 pipe. NIBCO later repeatedly denied responsibility when the product failed due to oxidative degradation during service, knowing what this testing had shown. Instead, NIBCO has almost invariably pointed to improper installation, excessive water temperature, excessive water pressure, atypical water chemistry, or other environmental conditions as the root cause of the failures.[42]

iii. Site Inspections

In this case and in the Meadow class action, Ms. Smith inspected the plumbing system at each named Plaintiff's home (except for the residence of James Monica, a named Plaintiff in this case), in an effort to determine if the manner of installation, excessive water temperature, excessive water pressure, atypical water chemistry, or some other environmental condition may have contributed to failure of the incident plumbing components.

At each residence, the water pressure was measured (typically at an outside hose bib), and a limited range of water chemistry tests were performed on-site by Ms. Smith. Hot and cold water samples were collected and preserved for subsequent laboratory analysis. The homeowner was interviewed to obtain an overview of leaks that had occurred in each residence and to determine if any changes had been made to the plumbing system.

NIBCO's experts were also on site for each plumbing system inspection. They separately performed water chemistry testing (including preservation of hot and cold water samples) and flow rate testing for each home that had not previously been replumbed. Ms. Smith witnessed all testing performed by NIBCO's experts during these inspections.

Including the incident pipes, 165 PEX plumbing assemblies and components were removed from these homes for laboratory inspection and analysis. The analyzed components included multiple incident pipes that had reportedly leaked during service.

[42] See footnotes 3-6.

NIBCO had previously evaluated at least at least 10 incident pipes and deemed them "Not Defective" (the six pipes identified in Table 2 for the Cole class action, plus four (4) additional pipes from the Meadow class action that were also evaluated and deemed "Not Defective" by NIBCO[43,44,45,46]). Numerous companion pipes that were removed from service in the same installations were also inspected for comparison. Ms. Smith additionally evaluated multiple brass fittings, stainless steel clamps, and/or valves associated with these incident plumbing systems.

The results of Ms. Smith's on-site water testing are summarized in Table 3. No evidence was found to suggest that improper installation, excessive bending, UV exposure, over-pressurization, excessive water temperature, or atypical water chemistry significantly contributed to the root cause of failure in any of the NIBCO PEX products.

Detailed water chemistry reports for laboratory testing are contained in Appendix 5. This testing was conducted by Pace Analytical, an NELAP accredited water chemistry testing laboratory. All tested parameters fell well within the range anticipated for potable water in the United States, and no anomalous condition was identified.

[43] NIBCO-Cole 00090306, Evaluation Response Letter #2015032007 (Susan Plisko); PLPLISKO-0063, 5/11/15 email from Ken McCoy – Confidential
[44] NIBCO-Cole 00087986, Evaluation Response Letter #2014102101 (Chad Meadow)
[45] NIBCO-Cole 00088028, Evaluation Response Letter #2014110407 (Kenneth McLaughlin)
[46] NIBCO-Cole 00024659 (Meadow-Line 226, McLaughlin-Lines 222 and 294, Plisko-Line 101) – ATTORNEYS' EYES ONLY

Table 3
Summary of On-Site Water Test Results

Plaintiff/ Class Member	Location	Maximum Water Pressure (psi)	Maximum Temp (F)	Maximum Free Residual Chlorine (ppm)	Dissolved Oxygen (mg/L)	pH (standard units)	Oxidation Reduction Potential (mV)
Meadow	Tennessee	92 (H)	148 (hot)	1.95 Cold 0.006 Hot	8.2 Cold 3.8 Hot	8.0 Cold 7.7 Hot	681 Cold 151 Hot
Plisko	South Carolina	60	120 (hot)	0.88 Cold 0.62 Hot	10.3 Cold 7.1 Hot	7.8 Cold 7.6 Hot	578 Cold 520 Hot
McLaughlin	Alabama	85 (H)	124 (hot)	1.33 Cold 0.96 Hot	8.4 Cold 5.3 Hot	8.6 Cold 7.9 Hot	623 Cold 613 Hot
Lawson	Alabama	not tested	122 (hot)	1.32 Cold 0.24 Hot	8.8 Cold 5.1 Hot	8.3 Cold 7.6 Hot	660 Cold 220 Hot
Cole	Tennessee	52	132 (hot)	1.0 Cold 1.11 Hot	8.4 Cold 6.4 Hot	7.1 Cold 7.0 Hot	530 Cold 496 Hot
McCoy	Georgia	60	112 (hot)	1.79 Cold 0.74 Hot	8.4 Cold 5.8 Hot	8.5 Cold 8.3 Hot	519 Cold 385 Hot
Boyd	Alabama	not tested	128 (hot)	1.58 Cold 1.31 Hot	9.1 Cold 5.3 Hot	8.8 Cold 8.1 Hot	495 Cold 478 Hot
McMahon	Texas	not tested	108 (hot)	1.54 Cold 1.07 Hot	5.8 Cold 7.4 Hot	8.7 Cold 8.8 Hot	519 Cold 108 Hot
Medders	Texas	40	136 (hot)	0.00 Cold 0.00 Hot	3.0 Cold 2.3 Hot	7.18 Cold 7.13 Hot	279 Cold 167 Hot
Peperno	Pennsylvania	55	144 (hot)	1.96 Cold 0.28 Hot	9.8 Cold 6.2 Hot	7.9 Cold 8.0 Hot	556 Cold 401 Hot
Sminkey	Oklahoma	58	160 (hot)	0.02 Cold 0.08 Hot*	8.9 Cold 4.0 Hot	7.5 Cold 7.4 Hot	249 Cold 131 Hot

*Interference Suspected

iv. Incident Pipes

The NIBCO 1006 PEX plumbing pipes are universally defective in their design and composition, leading to insufficient stabilization and oxidation of the PEX material. As a result of these latent defects, the pipes are unable to withstand the intended service environment, and are highly vulnerable to premature failure in potable water applications, due to the combined effects of oxidative degradation of the PEX material and creep rupture.

In hot and cold water plumbing applications, properly installed NIBCO PEX 1006 pipe will develop fine craze cracks (a network of interconnected tight, shallow, brittle cracks) at the interior surface of the pipe due to oxidative degradation. Once the craze cracks form, they will spontaneously grow by creep rupture because the pipe is under constant hydrostatic pressure. Cracks grow very easily once they initiate. Thus, once the process begins, the only way to prevent future leaks is to replace the PEX tubing.

Evidence indicates that NIBCO's manufacturing process for PEX 1006 pipe consistently resulted in insufficient stabilization at the interior surface of the pipe, potentially accompanied by oxidative degradation at the interior surface before the pipe even left NIBCO's facility.

"Oxidation Induction Time" is literally the time required to induce measurable oxidation in a specimen of a certain size and shape when exposed to concentrated oxygen at 200˚C.[47] Documentation produced by NIBCO shows that as-manufactured NIBCO PEX 1006 pipe that has never been exposed to water, repeatedly exhibited an Oxidation Induction Time (OIT) of less than 5 minutes at the interior surface of the pipe, whereas the outer diameter surface and mid-wall region of the same pipe exhibited an order of magnitude greater OIT. These samples were analyzed before the pipes were ever exposed to any source of oxidative degradation.

When Ms. Smith comparatively analyzed never-installed samples of NIBCO PEX 1006 pipe and NIBCO PEX 3308 pipe by Fourier Transform Infrared Spectrometry and OIT in prior investigations related to leaking NIBCO PEX 1006 pipe, similar results were noted.

In this class action, when field-returned samples from a residence utilizing well water that had not been treated with chlorine or chloramine (which would not be expected to significantly affect properly stabilized pipe), a similar loss of stabilization was noted at the interior surface of the pipe. This suggests that the pipe was likely placed into service with insufficient stabilization at the interior surface.

It is worth noting that NIBCO reportedly extruded its PEX 1006 pipe at 227-232˚C (440-450˚F),[48] which is approximately 30˚C hotter than the temperature used to deliberately induce measurable oxidation in the OIT test. Although the OIT test is run in a pure oxygen environment, some degree of oxidation would be expected to occur in air at the same temperature over a comparable period of time.

As a separate issue, many of the incident pipes exhibited non-uniform pipe dimensions, extrusion defects, and inclusions in the pipe wall that promoted crack initiation (which likely explains why some homeowners experience failure more quickly than others, even when their water pressure may have been lower). However, these conditions are not necessary for failure to occur. Many incident pipes cracked with no evidence of any discernible extrusion defect, dimensional variance, or other stress riser, so although these conditions are undesirable and indicative of a poorly-controlled manufacturing process, these manufacturing defects are merely exacerbating conditions and not a root cause.

Inspection of the incident plumbing systems revealed no correlation between the manner of installation, service environment, water temperature, water pressure, or water

[47] ASTM D3897-07 – *Standard Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry*
[48] Deposition of Earl Sexton, October 11, 2016 at 133:11-14.

chemistry, and the root cause of cracking. Most of the incident leaks occurred in nearly straight sections of pipe, although some leaks were noted at the exterior of typical bends (which would be a natural area of elevated stress in a properly installed plumbing system).

There is no way for a homeowner to identify these cracks before they penetrate the wall of the pipe, and there is no way for a homeowner to prevent the cracks, or halt their growth once they have formed.

Among the pipes associated with the Cole and Meadow class actions, the vast majority of the incident pipes exhibited visible evidence of oxidative degradation at the interior surface of the pipe, with coincident crazing. Most every pipe examined, even if only a few inches long, exhibited multiple cracks, with the orientation of cracking generally corresponding to the degree of bend (or lack thereof) in the sample. Longitudinal cracks tend to occur more often in straighter sections of pipe, whereas circumferential cracks occur more often in curved sections of pipe.

No evidence of excessive bending was observed in any of the approximately 165 pipe samples associated with the two class actions. In fact, most of the pipes were remarkably straight, exhibiting little or no discernible curvature. Straight pipes and pipes with typical bends were found to exhibit comparable numbers of cracks with comparable crack morphologies, typically varying only in orientation. In several cases, more than 100 discrete cracks were noted in less than three inches of pipe length, with clear evidence of crack coalescence. NIBCO PEX tubing was marketed as “bendable” and “flexible”, with a specified minimum bend radius that is dependent upon the diameter of the tubing.

In each case, the interior surface of each pipe exhibited a chalky-looking, heavily oxidized and embrittled interior surface similar to that shown in Figure 4, with multiple cracks and extensive crazing. Many of the larger cracks were found to be “gaping” open at the inner diameter (ID) surface (reference encircled crack, Figure 5), indicating that a high level of residual stress existed in the PEX material from manufacturing. Extensive crazing consistent with oxidative degradation was observed in nearly every pipe examined. Inspection of the interior surface of the pipes adjacent to the cut ends often revealed multiple cracks that had not yet propagated entirely through-wall (reference Figures 2 through 6). These cracks initiated at the interior surface of the pipes, and extended up to 50% through-wall with a pronounced “v-notch” morphology (again, indicative of a high level of residual stress in the pipe wall). These cracks would have eventually formed through-wall leaks if they had been left in service under constant hydrostatic pressure.

Little or no evidence of yielding or ductility was associated with the incident fractures, indicating that excessive pressure did not cause these pipes to fail (i.e., excessive pressure was not a necessary condition for failure to occur). This was further supported by the fact that six of the eight Plaintiff’s homes that were evaluated for water pressure (75% of those tested) exhibited pressures well below the 80-psi maximum permitted for NIBCO PEX tubing in contact with hot chlorinated water (reference Table 3).

Additionally, most of the homes employed hot water expansion tanks and/or pressure reducing valves (PRVs).

The two homes that did exhibit excessive pressure (McLaughlin at 85 psi, and Meadow at 92 psi) did not experience earlier failures than homes with significantly lower pressure; and the cracks observed in pipes from these homes were virtually identical to cracks observed in pipe from homes with lower pressure. Additionally, Meadow (whose home exhibited the highest water pressure of all homes evaluated) experienced the longest "time to first leak" of all homes evaluated, and lower oxidation indices at the interior surface of the PEX pipe than Cole, whose water pressure was only 52 psi. This indicates that excessive pressure did not contribute significantly to crack initiation or to oxidative degradation in the PEX tubing, although elevated pressure would be expected to accelerate the rate of crack growth through the wall of the pipe (all other things being equal), once the craze cracks that formed due to oxidative degradation began to grow by creep rupture.

Ms. Smith did not conduct a site inspection at the Monica residence, and water pressure was not tested at the Boyd and McMahon residences because these plumbing systems had been completely replaced.

Some of the cracks in these pipes initiated at extrusion lines (die lines) at the interior surface and/or exterior surface of the pipe. Other cracks were found to have initiated at small inclusions (believed to be brittle specks of oxidized polymer that entered the process stream during extrusion) and/or at small discontinuities (such as dimples) in the pipe wall. As noted above, however, these localized stress risers were merely an exacerbating condition, and not a root cause for the incident leaks.

The orientation, morphology, shape, width, and location of the incident leaks at issue in the Cole and Meadow class actions were virtually identical to the features observed in the 750+ incident pipes that Ms. Smith has examined in other cases. The surrounding interior surfaces were also nearly identical.

v. Brass Fittings & Clamps

Two named plaintiffs from the Cole class action (Medders and Monica) have experienced multiple fitting and clamp failures that resulted in discernible water leaks. Evidence of the same failure mechanism was also observed in brass fittings from the Peperno residence, although the Pepernos had not yet detected a through-wall leak in a fitting. Brass fittings from the Medders, Monica, and Peperno residences are shown side-by-side in Figure 7, in the as-received condition.

An incident brass fitting that fractured during service at the Medders residence is shown in Figure 8. Corroded brass fittings and fractured clamps from the Monica residence are shown in Figures 9 and 10, respectively.

Select brass fittings and clamps were analyzed by stereomicroscopy, metallography, scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDX), and inductively coupled plasma spectrometry with atomic emission spectrometry (ICP-AES) to assess the condition of the metal components and determine the root cause of failure for each.

Results indicated that the brass fittings leaked due to dezincification corrosion and transgranular stress corrosion cracking that initiated at the interior surface of the fittings (where the brass material was in contact with the potable water). The incident clamps fractured due to chloride-induced stress corrosion cracking, which can occur when a susceptible austenitic stainless steel is simultaneously exposed to chlorides and static tensile stress.

All NIBCO brass insert fittings made from brass alloys containing greater than 15% zinc are inherently susceptible to dezincification corrosion and stress corrosion cracking in potable water applications, and all NIBCO stainless steel PEX clamps are universally vulnerable to chloride-induced stress corrosion cracking in PEX plumbing applications.

The stainless-steel clamp is used to seal the PEX tubing against raised sealing barbs on the outlet of the brass fitting. To achieve this seal, the clamp is tightened around the pipe until stresses in the clamp approach the tensile strength for the stainless-steel material (as evidence by “necking,” or narrowing, that occurs near the windows of the clamp, as shown by the white arrows in Figure 10C). A typical clamp crack is encircled in Figure 10D.

No evidence was found to suggest that improper installation, freezing, misuse, or abuse contributed significantly to failure of the incident brass fittings and clamps.

NIBCO PEX insert fittings made from brass alloys containing greater than 15% zinc, and NIBCO PEX clamps made from austenitic stainless steel, are defectively designed for the intended application due to improper material selection.

Safer alternative designs were available at the time the incident fittings and clamps were manufactured. PEX fittings made from copper alloys containing less than 15% zinc (red brass and bronze alloys) and plastic (which NIBCO currently sells) are generally regarded as *immune* to both dezincification corrosion and stress corrosion cracking. In comparable service environments, NIBCO’s copper crimp rings have proven to be a more robust alternative to the NIBCO stainless steel clamps.

NIBCO knew or should have known that its stainless steel PEX clamps and ASTM F1807 brass insert fittings made from high zinc brass alloys (brasses containing >15% zinc) would fail prematurely in the intended service environment.

Figure 7: Representative corroded brass fittings from the Cole class action. (A) PPX-7 Fitting Exterior, James Monica; (B) PPX-7 Fitting Interior after sectioning, James Monica; (C) PPX-88, Peperno; (D) PPX-96, James Medders. Although none of the brass fittings from the Meadow case exhibited a similar degree of dezincification, stereomicroscopy revealed evidence of dezincification in nearly every fitting examined. Eventually, the corrosion will penetrate the wall of the fitting, allowing water to weep through.

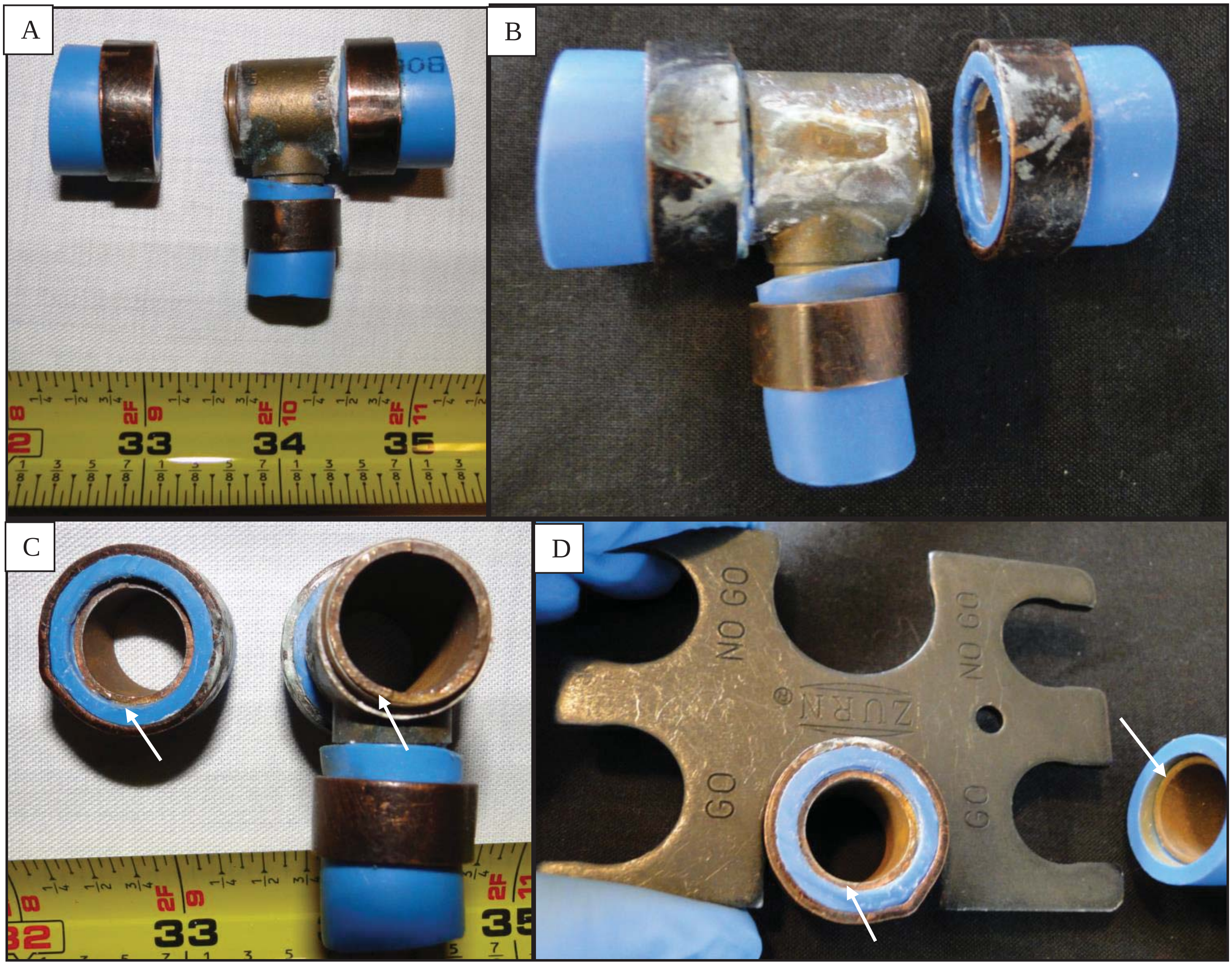


Figure 8: (A, B) Front and back views of an incident fractured brass fitting from the Medders residence (Medders Sample PPX-99), shown in the as-received condition. One outlet from this fitting had completely fractured away from the rest of the fitting during service, resulting in an appreciable loss of water. (C) Separation fractures (arrows) from the incident brass fitting, and (D) PEX Go-no-go gauge demonstrating that the copper crimp ring was properly crimped. This fracture was found to have resulted from the combined effects of transgranular stress corrosion cracking and dezincification corrosion.

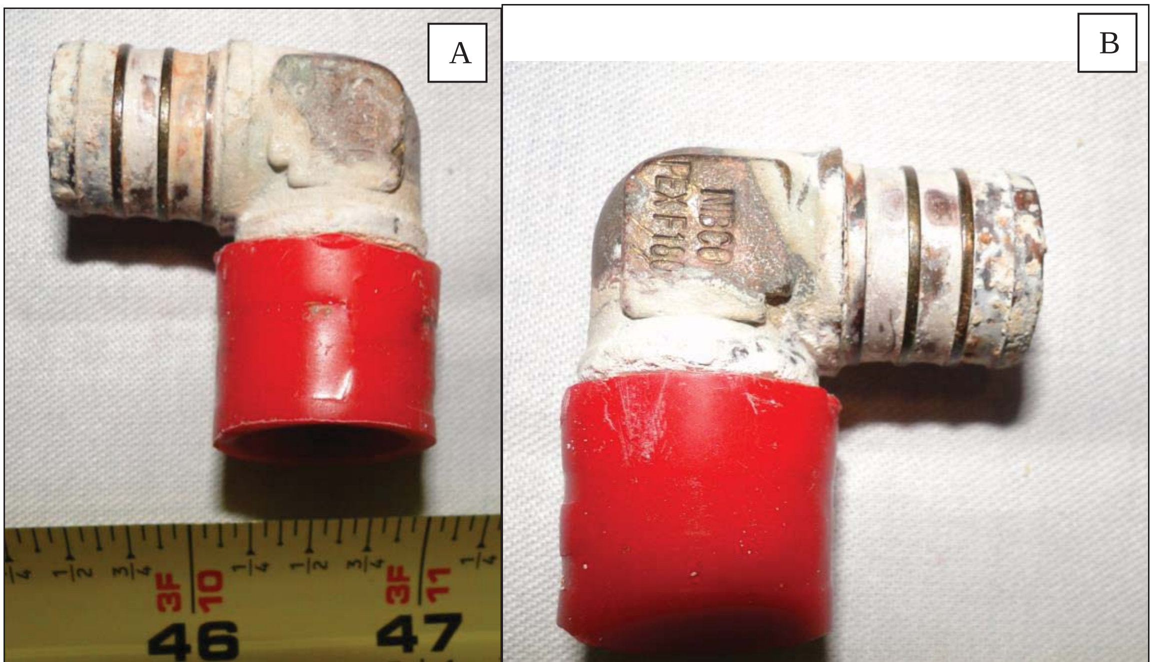


Figure 9

Incident corroded brass insert fitting, Monica PPX-11, shown in the as-received condition: (A) front view, (B) back view (note NIBCO labeling), and (C) dezincification corrosion "meringue" (arrow) inside incident fitting. Dezincification meringue can completely occlude plumbing fittings, severely impeding water flow.

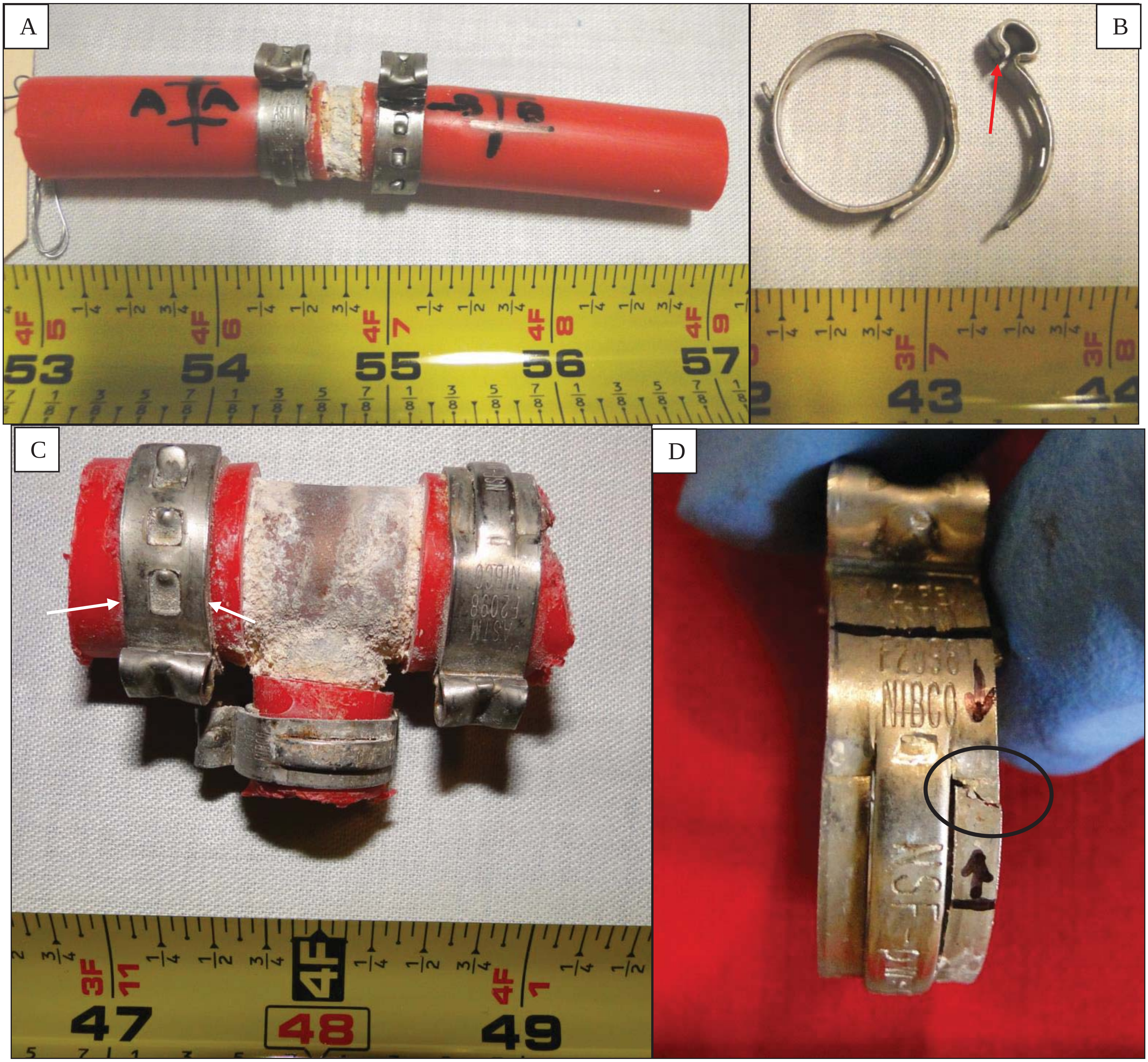


Figure 10: (A) Monica Sample PPX-8, showing dezincification of a brass coupling with adjacent cracked stainless steel PEX clamps. (B) Cracked clamp from Monica PPX 11. This clamp fractured at the ear (arrows) due to chloride-induced stress corrosion cracking. (C) Monica Sample PPX-9, showing a corroded brass fitting and adjacent stainless steel clamps with signs of stress corrosion cracking (brown deposits at arrows). When a brass fitting corrodes in this manner, chloride-rich water can seep through the wall of the fitting, wetting the adjacent stainless steel clamps with incompatible chlorides. The “necking” (narrowing) visible at the white arrows indicated that the clamp was in a highly-stressed state. (D) Cracked clamp (crack is encircled) from Monica PPX-8 (reference View A).

TASKS UNDERTAKEN

Ms. Smith has personally undertaken the following tasks to evaluate the root cause of failure for the incident pipes at issue in this class action:

1. The residential plumbing systems in each named Plaintiff's home from the ***Cole*** and ***Meadow*** class actions (except for the James Monica residence) was inspected and evaluated to determine if the manner of installation, water temperature, water pressure, flow rate, water chemistry, or some other external condition may have contributed to failure of the incident pipes, fittings, and/or clamps.

2. During each site inspection, the homeowner was interviewed to obtain a general overview of the approximate leak history and to identify any changes that may have been made to the plumbing system since it was originally installed.

3. During each home inspection, water chemistry testing was performed on-site, and additional hot and cold water samples were collected and preserved for laboratory analysis.

4. Over 110 samples of failed and non-failed NIBCO PEX pipes from the named Plaintiffs' homes in the Cole class action were visually inspected, photo-documented, and examined using a stereomicroscope at up to 70X magnification to evaluate the leak sites and assess the condition of each pipe.

5. An additional 55 samples of failed and non-failed NIBCO PEX pipes from the named Plaintiffs' homes in the Meadow class action were also visually inspected, photo-documented, and examined using a stereomicroscope at up to 70X magnification.

6. Results of the site inspections noted above were compared to the results of similar efforts previously undertaken by Ms. Smith to evaluate the root cause of failure for 500+ leaking NIBCO PEX pipes installed by Christianson Plumbing in and around San Antonio, Texas.

7. Results of the site inspections performed for the Cole class action were also compared to the results of similar efforts previously undertaken by Ms. Smith to evaluate the root cause of failure of NIBCO PEX pipes installed in an approximately a 150-unit condominium development in Baja Mexico.

8. One hundred and sixty-five (165) failed and non-failed pipes and dozens of associated corroded brass fittings and fractured clamps from hot and cold plumbing applications related to the Cole and Meadow class actions were destructively tested and analyzed to further evaluate the root cause(s) of failure for the incident plumbing components. The components were removed from service in eleven (11) different Plaintiff's homes and four (4) class members' homes, in eight different states.

9. Most or all samples from the Cole and Meadow class actions were dimensionally inspected in accordance with ASTM F876 and ASTM D2122 to evaluate the outer diameter and wall thickness of each pipe.

10. Eighteen select pipe samples (including incident pipes and companion pipes that remained in service in the same installation) were tested and analyzed in general accordance with ASTM D2765 to evaluate the degree of cross-linking in the PEX material, using xylene as the solvent. For comparison purposes, three duplicate pipe samples were additionally evaluated in accordance with ASTM D2765, using Decalin as the solvent to determine the degree of cross-linking.

11. Representative tubing samples were analyzed by Fourier Transform Infrared Spectrometry in the Attenuated Total Reflectance (ATR) mode in general accordance with ASTM F2102 to assess and map the degree of oxidation at various locations within the wall of the tubing. Each sample was evaluated at 90 degree intervals around the pipe circumference (12 o'clock, 3 o'clock, 6 o'clock, and 9 o'clock). At each 90-degree interval, the pipe was evaluated at the outer diameter surface, the inner diameter surface, and at approximately mid-wall. A total of twelve locations were evaluated for each sample. The resulting spectra were then analyzed to determine the carbonyl index at each location so that the distribution of oxidation within the pipe wall could be assessed.

12. To evaluate the degree of residual stabilization in the PEX material, representative tubing samples were destructively analyzed to measure the oxidation induction time (OIT) in general accordance with ASTM D3895– *Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetery*.

13. Water chemistry testing was performed in ten (10) named Plaintiffs' homes and one (1) class member's home from the Meadow and Cole class actions to determine if there was something unusual about the water that might have contributed to failure of the incident pipes. In addition to the water chemistry testing performed on-site, additional hot and cold water samples were collected from each home, preserved, and then forward to an NELAP accredited laboratory for additional analysis.

14. Over 150,000 pages of documents (including the full set of files produced by NIBCO) related to the design, manufacture, sale, distribution, quality assurance, marketing, testing, certification, and performance of NIBCO PEX products were electronically reviewed by Ms. Smith.

15. Deposition testimony was reviewed for each named Plaintiff in the Cole and Meadow class actions to verify the installation history and leak history for the NIBCO PEX plumbing pipes.

16. The date codes, reel codes, size, and color of the incident pipes associated with each class action were analyzed to determine if any correlation existed to any specific production demographic.

BASIS OF OPINIONS

Ms. Smith personally examined 110 NIBCO PEX plumbing assemblies or components that had reportedly leaked during service in hot and cold water residential plumbing applications in Tennessee, Georgia, Alabama, Texas, Oklahoma, New Jersey, and Pennsylvania, on behalf of the named Plaintiffs in the Cole class action.

For comparison purposes, Ms. Smith concurrently examined an additional 55 NIBCO PEX plumbing assemblies and associated brass fittings and stainless steel clamps that were removed from the homes of named Plaintiffs in the Meadow class action. Many, but not all, of the components examined had leaked during service. The plumbing assemblies analyzed in the Meadow class action were previously installed in hot and cold water plumbing applications in South Carolina, Tennessee, and Alabama. Four additional homeowners who are not named Plaintiffs in either class action also provided samples of leaking NIBCO PEX pipe that Ms. Smith analyzed in detail.

Many of the analyzed assemblies contained multiple components (pipe, fittings, and clamps), and some contained multiple segments of PEX pipe. All samples were removed from homes where at least one NIBCO plumbing product had leaked (either a NIBCO PEX pipe or NIBCO brass fitting). Companion NIBCO PEX 1006 pipes that had not yet leaked in the same installation were also evaluated for comparison, along with associated brass fittings and stainless steel clamps.

Between the two class actions, one hundred and sixty-five (165) failed and non-failed pipes and dozens of associated corroded brass fittings and fractured clamps from hot and cold plumbing applications in eight (8) different states were destructively tested and analyzed to further evaluate the root cause(s) of failure for the incident plumbing components.

Ms. Smith also reviewed and analyzed the installation and leak history for the Plaintiffs' incident plumbing systems where leaks had occurred. Additionally, Ms. Smith reviewed various manufacturing records and other documents produced by NIBCO and third parties in response to Plaintiffs' document production requests.

These efforts collectively revealed the following:

Visual Inspection and Stereomicroscopy

All available incident pipes were visually examined in the as-received condition both with the unaided eye and at up to 70X magnification using a research-grade stereo microscope equipped with a digital camera. Stereomicroscope images associated with this inspection are contained in Appendix 6.

A. In all cases where the manufacturer's labeling could be seen on the incident tubing, such labeling was consistent with NIBCO PEX plumbing pipe.

B. The examined incident pipes all failed in a consistent manner due to brittle cracks that initiated at the interior surface of the tubing. Representative brittle cracks are shown in Figure 11. Some of these cracks grew in a circumferential direction (perpendicular to the longitudinal axis of the pipe) while others grew in a longitudinal direction (parallel to the longitudinal axis of the pipe) or at a 30 to 45- degree angle relative to the longitudinal axis of the pipe.

C. The incident cracks were typically longer at the interior surface of the tubing that at the exterior surface, suggesting that the cracks initiated at the interior surface. The interior surface initiation was confirmed by the presence of additional cracks that had not yet propagated completely through the wall of the tubing, and by fracture features observed on multiple exposed fracture surfaces associated with incident leaks. Each incident crack and each partial crack that had not yet extended entirely through-wall exhibited similar features. Representative examples are shown in Figure 12. The incident fractures were exposed by Ms. Smith during laboratory inspection to allow for analysis of fracture features.

D. Cracks that formed at the exterior of a bend in the tubing (regardless of how slight or pronounced that bend might be) tended to grow in the circumferential direction; while cracks that formed at the interior of a bend in the tubing tended to grow in the longitudinal direction. Cracks that formed in straight lengths of tubing tended to grow in the longitudinal direction or at a 30 to 45-degree angle relative to the tubing axis.

E. The degree of bend in the pipes appears to influence the *location* and *orientation* of the cracks due to localized stress concentrations. However, none of the pipes associated with the Cole and Meadow class actions were excessively bent, and both longitudinal and circumferential cracks have sometimes been observed in the same piece of pipe, depending upon where the crack was located relative to a bend. The presence of >100 similar cracks in short sections (<3-inches long) of <u>straight</u> pipe (where no localized stress concentration resulting from the manner of installation existed), clearly demonstrated that these pipes were destined to fail due to oxidative degradation and creep rupture, regardless of whether installation-related stress concentrations existed. Although in some cases, the *location* and *orientation* of the cracks appeared to have been influenced by the manner of installation, most pipes failed in the absence of significant bending stresses and/or localized stress concentrations.

F. The interior surface and exterior surfaces of all available incident pipes from each class action were examined at up to 70X magnification using a research-grade stereo-microscope. Evidence of oxidation was readily-apparent at the interior surface of nearly every pipe examined. The interior surfaces generally exhibited a chalky appearance and/or crazing that was visible adjacent to the cut ends of each sample. Typical areas of crazing are shown in Figures 4 and 13. These features were consistent with oxidative degradation of the PEX material.

G. Crazing indicative of oxidative degradation and embrittlement of the PEX material was observed at the interior surface of every incident pipe examined, and numerous larger cracks with appreciable depth were found to have propagated from these fine crazes, in a manner consistent with oxidative degradation of PEX. (Cole Sample PPX-23, for example).

H. Past visual inspection results related to a 2015 examination of four coils of never-installed NIBCO PEX tubing were reviewed. These pipe coils had been retained by Christianson Air Conditioning and Plumbing ("Christianson") under lock and key in a climate-controlled, darkened room in the as-received, as-coiled condition. The manufacturer's labeling on two of these never-installed coils of NIBCO PEX pipe confirmed that they were manufactured from the same PEX formulation, using the same processing parameters[49], as the incident 1006 PEX pipe that is at issue in this case. The other two coils of never-installed pipe were made from NIBCO's 3308 PEX formulation[50] (which was a re-designed formulation that NIBCO introduced in 2012 primarily to provide improved resistance to oxidative brittle failure in chlorinated water).

[49] NIBCO-Meadows 00128077 at 00128106 (photos comparing installed to never-installed pipe)
[50] NIBCO-Meadows 00128077 – Confidential – Paragon Polymer Consulting Report

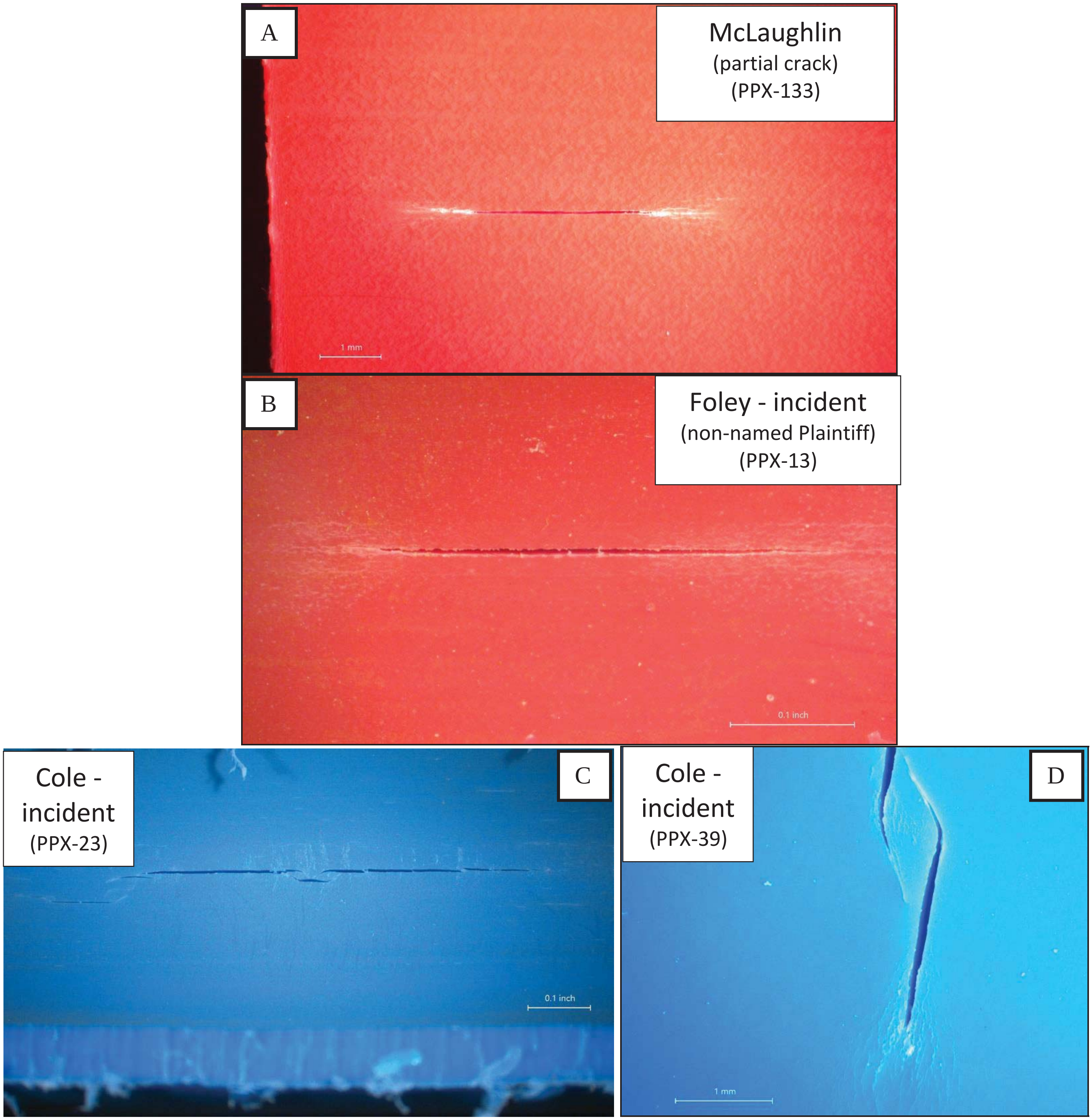


Figure 11: Representative brittle cracks as seen at the interior surface of the pipe, using a stereomicroscope: (A) the McLaughlin residence (Sample PPX-133, longitudinal partial crack that had not yet propagated entirely through-wall), (B) the Foley residence, a non-named class member (Sample PPX-13, longitudinal incident crack), (C) the Cole residence (Sample PPX-23, longitudinal incident crack), and (D) the Cole residence (Sample PPX039, circumferential incident crack).

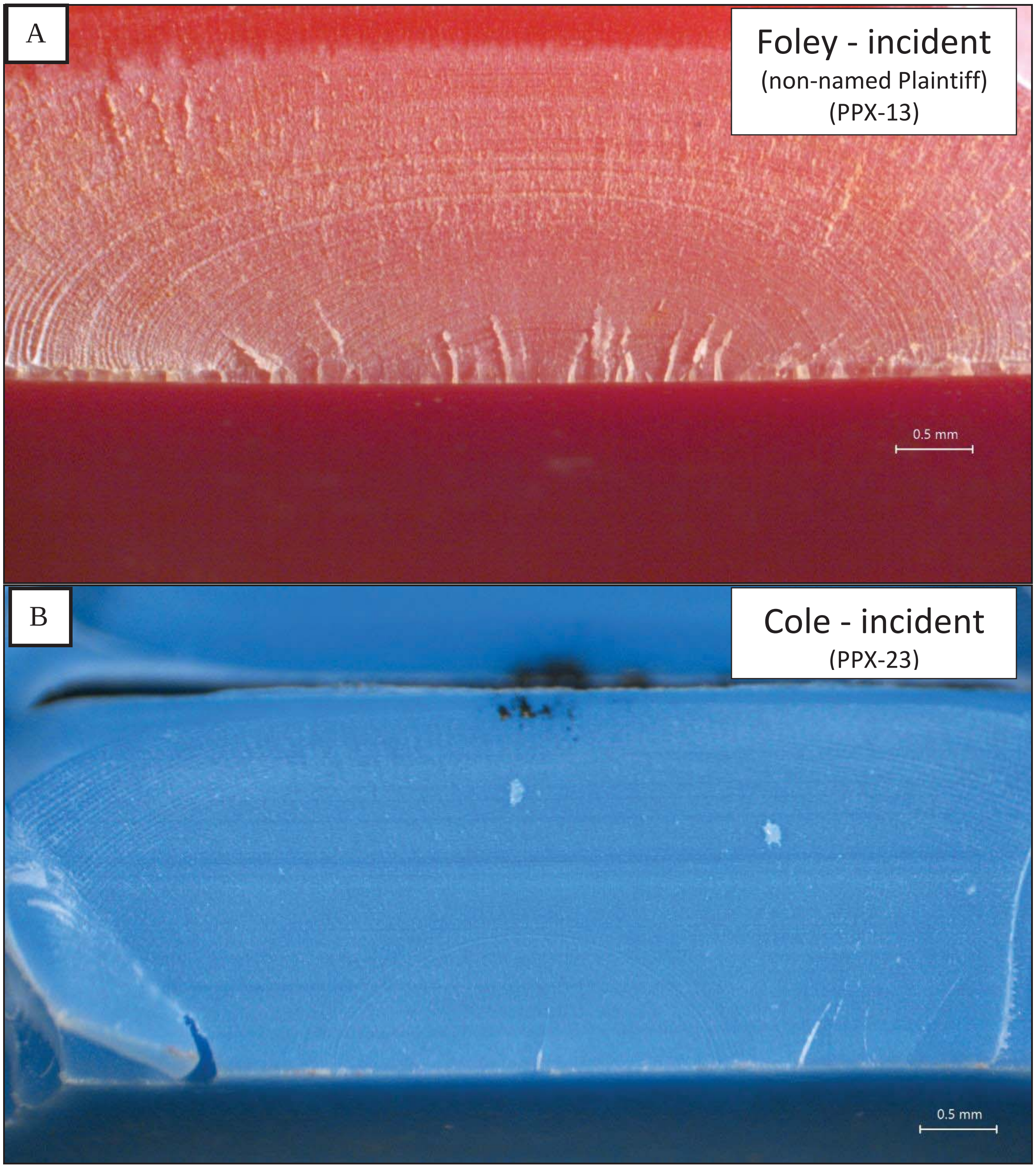


Figure 12: Stereomicroscope images of exposed fracture surfaces from the incident cracks in (A) Foley Sample PPX-13 and (B) Cole Sample PPX-23 (reference Figure 11). Most fractures initiated at multiple locations at the interior surface of the pipe, and multiple crack fronts merged to form a larger continuous crack, unless an inclusion existed at the fracture origin. No stress whitening, yielding, or appreciable ductility was observed at either crack or facture. Extensive crazing was noted at the interior surface of each pipe. These fractures initiated due to brittle oxidative degradation, and propagated by creep rupture. Little or no evidence of ductility was observed at the interior surface of the pipe, adjacent to either fracture.

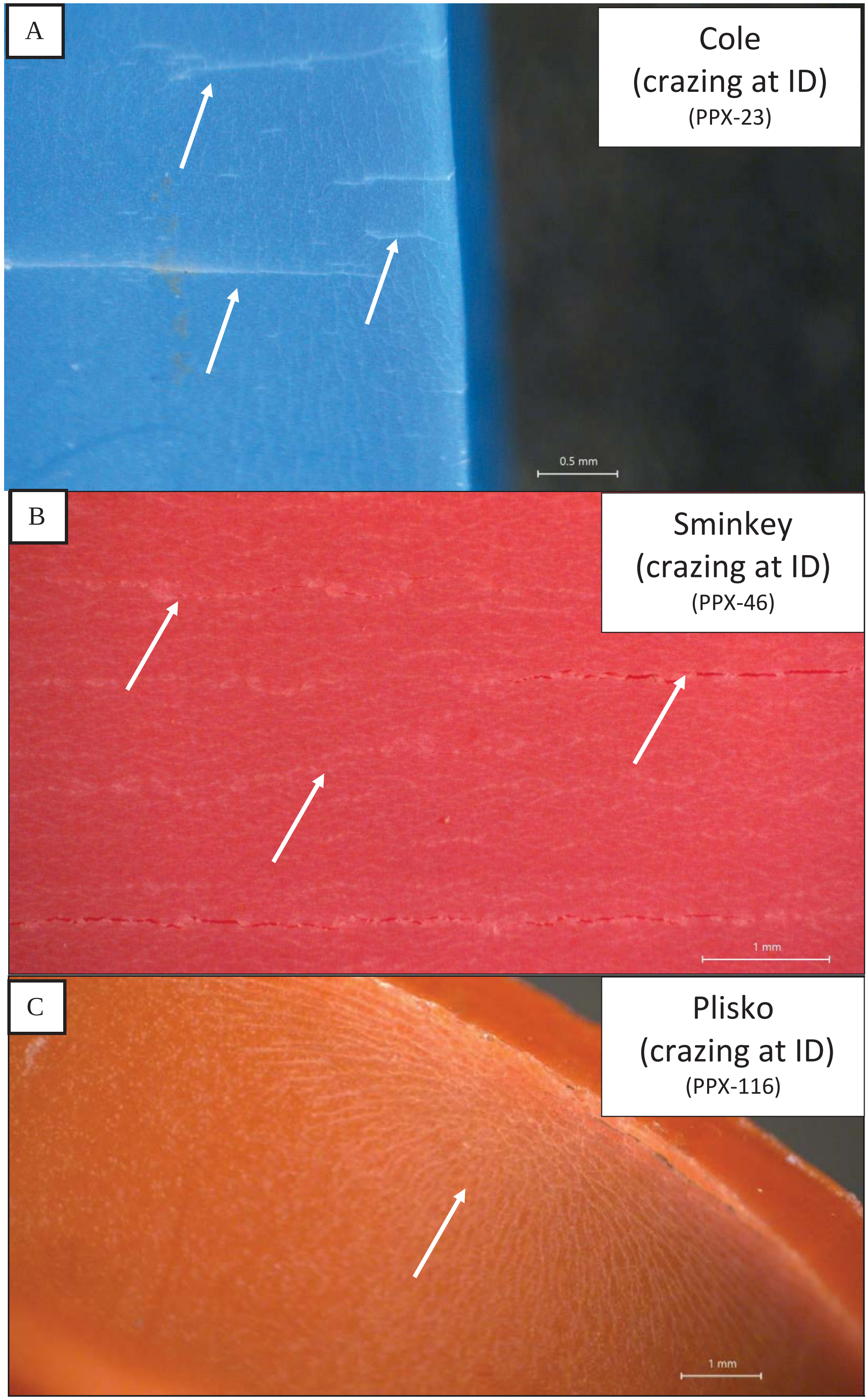


Figure 13:

Representative craze cracking (arrows) at the interior surface of several named Plaintiff's incident pipes. These crazes are seen most easily at the cut end of the pipe, where the stress from cutting has caused the crazes to open. Very fine crazes that were not as readily-apparent were observed throughout each pipe, as seen in View A. Such crazing is consistent with oxidative degradation.

Note that the orientation of the craze cracks varies, with some crazes oriented longitudinally, some oriented in the transverse direction, and some oriented at a 30 to 45-degree angle. Each and every one of these craze cracks has the potential to grow through wall.

I. In many cases, gaping brittle cracks and/or tight fine cracks that had not yet propagated through wall were also observed at the interior surface of the pipes, in addition to the through-wall cracks that allowed the pipes to leak. The appreciable crack opening and v-notch morphology associated with the gaping cracks revealed that the PEX material often contained a high level of residual stress from manufacturing, and that crack initiation and propagation were significantly influenced by this residual stress. The location, orientation, and morphology of these brittle cracks were consistent with oxidative degradation of the PEX material.

J. The absence of any appreciable deformation, yielding, or ductile fibrils within the brittle cracks suggested that the material at the interior surface of the tubing (where the cracks initiated) was embrittled by oxidation, and that the total stress associated with growth of the crack through the wall of the tubing (where the PEX material was not appreciably oxidized) was below the yield strength for the PEX material. This further indicated that over-pressurization did not likely contribute significantly to failure of the incident pipes.

K. In all but a couple of cases (two samples), no unusual surface deposits were observed at the interior surface of the pipes. Most pipes exhibited a light layer of tan and/or white deposits, as is typically seen in tubing removed from potable water installations. One pipe that exhibited a unique appearance contained a heavier layer of dark brown deposit, believed to be corrosion product from an adjacent corroded brass fitting. Another pipe exhibited a discrete spot of material believed to have resulted from organic activity in the water (algae and/or bacterial colonization), which appeared to have no impact on the PEX material. No evidence was found to suggest that atypical water chemistry or unusual surface deposits contributed to failure of the incident pipes. Neither of these conditions is believed to have contributed significantly to failure of the incident pipes, as many other pipes failed in the absence of similar deposits.

L. Many of the incident pipes were found to exhibit longitudinal extrusion lines (or “die lines”) at the interior and/or exterior surfaces of the pipe. Such features are considered to be manufacturing defects, and are specifically prohibited by ASTM F876. In many cases, multiple extrusion lines extended the full length of the pipe, and they were often distributed at regular intervals around the entire tubing circumference. These extrusion lines clearly offered preferential sites for crack initiation, however, a significant number of incident pipes failed in the absence of any observed extrusion defect, indicating that the presence of a surface discontinuity was not necessary for failure to occur. The inherent lack of stabilization was sufficient for the pipes to fail, even when there was no localized stress concentration.

M. Analysis of the manufacturing date codes printed on the incident pipes (when such dates codes were included with the tubing sample) revealed that the incident pipes were manufactured by NIBCO over a period of years ranging from 06/22/2006 to 5/25/2011. Failures occurred in red, blue, terra cotta, and white

pipes, in sizes ranging from ½-inch to 1-inch diameter. No evidence was found to suggest that the insufficient stabilization that caused these pipes to fail was confined to one or more specific lots of pipe. Documented date codes associated with each class action are presented in Appendix 7.

N. Several of the incident pipes exhibited manufacturer's print that curved around the exterior surface of the tubing. This suggested that the tubing likely twisted during the labeling process, which may have imparted torsional stress into the PEX material. Although this did not *cause* the pipes to fail, residual torsional stress in the PEX material would explain why some of the cracks grew preferentially at a 30 to 45-degree angle relative to the longitudinal axis of the pipe. Experience has taught that through-wall cracks in the defective NIBCO PEX 1006 pipe normally grow in the longitudinal or transverse (circumferential) direction. If the tubing twisted during the labeling process, it may very well have twisted during the extrusion process as well, thereby creating torsional residual stress fields in the pipe wall.

The presence of curved print is further noteworthy because it also constitutes a glaring cosmetic defect that NIBCO did not reject during the quality assurance inspection process. A cursory analysis of quality assurance records produced by NIBCO revealed no reference to curved print or to twisting of the tubing, and tubing with curved print clearly made its way into the Plaintiffs' homes. It appears that NIBCO either did not object to their tubing being distributed with curved print, or they failed to identify this obvious defect. This suggests a very lax and/or poorly-controlled manufacturing process.

O. No appreciable evidence of discoloration or fading that might suggest excessive exposure to UV radiation or heat was observed.

P. No evidence was found to suggest that misuse, freezing, external damage, or abuse contributed significantly to failure of the incident pipes.

Q. Three Plaintiffs in the Cole class action experienced leaks in NIBCO brass fittings, and many (if not all) of the remaining brass fittings associated with the pipes at issue in the Cole and Meadow class actions exhibited some degree of dezincification corrosion. Although no *leak* was reported in conjunction with these fittings in the Meadow class action, evidence from the Cole class action where through-wall leaks *did* occur in at least three homes suggests that the Meadow fittings would have also failed prematurely due to dezincification corrosion or stress corrosion cracking. The latent failure process was already underway.

R. NIBCO knew, or should have known, that all brass alloys containing greater than 15% zinc are vulnerable to dezincification corrosion and stress corrosion cracking, and that this failure mechanism could be prevented by choosing a brass material that contained less than 15% zinc, or limiting their fitting product line to plastic fittings only. Evidence suggests that NIBCO was fully aware of the

causes of dezincification corrosion and how to prevent it,[51,52] and that they knew as early as 2007 that their insert brass fittings for PEX tubing were experiencing leaks due to dezincification corrosion.[53] Yet, NIBCO did not recall the defective fittings, and they made no effort to warn homeowners that these failure mechanisms could occur. Instead, they continued to sell the defective fittings.

S. Energy Dispersive X-ray Spectroscopy revealed significant concentrations of chlorine and oxygen at the interior surface of failed and non-failed pipes. These findings were consistent with chlorine-induced oxidative degradation of the PEX material. Lesser quantities of minerals that are routinely found in potable water) were also detected at the interior surface of the incident tubing. No atypical surface deposits were detected, further indicating that the failures were not appreciably influenced by atypical water chemistry.

T. Fourier Transform Infrared Spectrometry (FTIR) was used to evaluate and map the degree of oxidation in the incident pipes and companion pipes from the same installation, at twelve different locations around each pipe wall. The incident pipes showed extensive, pervasive oxidation at the interior surface around the entire tubing circumference, with comparatively little or no evidence of oxidation at the exterior surface and mid-wall region. These results confirmed that the incident tubing was sufficiently oxidized to cause brittle cracking at the interior surface of the tubing.

U. Scanning electron microscopy revealed that the brittle oxidized layer at the interior surface of the pipe extended to a depth of over 100 microns in some instances, causing pervasive cracking and embrittlement at the interior surface.

V. No appreciable evidence of abrasion, deformation, or cutting was observed in conjunction with most cracks in the incident tubing, indicating that the tubing failures were not significantly influenced by external mechanical damage.

W. No appreciable evidence of discoloration, crazing, crack branching, or swelling was observed in the vicinity of the through-wall cracking in the incident tubing, indicating that the failures did not result from atypical water chemistry, UV degradation, or atypical chemical exposure.

X. No evidence was found to suggest that improper installation caused these incident pipes to fail.

[51] NIBCO-Meadows 00013967 at 00014051
[52] NIBCO-Meadows 00011536 at 00011567
[53] NIBCO-Meadows 00017056-00017115

Dimensional Inspection

Outer Diameter:

The outer diameter of each incident pipe and most companion pipes was evaluated in accordance with ASTM F876 and ASTM D2122.

Results revealed, as shown in Appendix 8 that sixty-six percent (66%) of the examined pipes did not conform to the outer-diameter dimensional requirements of ASTM F876, as they exhibited an average outer diameter that exceeded the permitted maximum.

Although it remains unknown if the excessive tubing diameter resulted from defective manufacturing and/or from expansion during service due to relaxation of the tubing after uncoiling and/or hydrostatic pressure during service, the following conclusions can be drawn:

i. The excessive tubing diameter did not, in and of itself, contribute significantly to failure of the incident tubing, and

ii. With only two exceptions (McLaughlin and Meadow) the water pressure measured in each Plaintiffs' home from the Meadow and Cole class actions was well below 80 psi (within the range permitted for NIBCO's PEX 1006 pipe). No evidence was found to suggest that excessive pressure contributed significantly to failure of the incident tubing, even when the pressures slightly exceeded 80 psi, as it did at the McLaughlin and Meadow residences.

NIBCO's Quality Assurance records for Dimensional Inspection revealed that these pipes were likely *manufactured* with an excessively large outer diameter. Reel after reel of NIBCO PEX tubing manufactured from 2006 through 2010 was routinely found to exhibit excessive outer diameters and to be excessively out-of-round.[54] This was true for all colors and all sizes of pipe.

Exemplar dimensional inspection records showing these non-conforming conditions are contained in Appendix 9. In almost every instance of dimensional non-conformity, no evidence was found to indicate that pipes with excessive outer diameter were flagged or rejected by NIBCO due to the non-conforming condition, or that any steps were taken to correct the non-conforming condition. Thus, it is reasonably probable that NIBCO sold tubing that exhibited an excessively large outer diameter.

In fact, two of the pipes from the McLaughlin residence (PPX-146 and PPX-141) exhibiting manufacturing date code "10/01/09-2 FB04-227-1-09" were confirmed to have been manufactured with an excessively large outer diameter. Examination of NIBCO's Quality Assurance Dimensional Inspection record for this reel of pipe

[54] Reference NIBCO-Cole 00068913 at 00068935; 00068986; 00068987; 00069027; 00069075; 00069076; 00069107; 00069163 and NIBCO-Cole 00069365 at 00069412; 00069446; 00069473; 00069480; 00069481; 00069501; 00069505; 00069515 and NIBCO-Cole 00070654 at 00070669; 00070772; 00070836 for examples.

revealed, as shown below, that the outer diameter at the time of manufacture was 0.631-inches (which did not conform to the 0.621-0.629-inch range permitted by ASTM F876)[55]. The pipe was also found to have been excessively out-of-round at the time of manufacturing, exhibiting an "Out of Roundness" (the difference between the maximum and minimum measured outer diameter) of 0.028-inch, which was well in excess (175%) of the 0.016-inch maximum permitted by ASTM F876. This pipe was not rejected for these dimensional non-conformities, but rather was sold by NIBCO as being compliant with ASTM F876.

An associated comment at the bottom of the dimensional inspection record for the McLaughlin pipe states, "*Oversized OD within error of calipers." However, the "Max./Min. OD" column in this data record reveals that the maximum pipe outside diameter (OD) was 0.645-inch (well above the upper limit of 0.629-inch per ASTM F876) and the minimum pipe OD was 0.617-inch (well below the lower limit of 0.621 per ASTM F876). NIBCO did not correctly evaluate this pipe, as the "average" value that NIBCO reported was merely the numerical average of the maximum and minimum OD values, rather than being an average of at least six outer diameter measurements as required by ASTM D2122-98 (2004).[56]

Clearly, NIBCO cannot rely upon excessive outer diameters that are measured in field-returned pipe to determine if a pipe was exposed to excessive pressure during service, as numerous pipes were sold into the stream of commerce with excessive outer diameters. Additionally, some degree of expansion will occur over time due to exposure to normal hydrostatic pressure, even when the pressure is not excessive, and the degree of expansion will vary dependent upon factors such as temperature, the magnitude of the water pressure, and the degree of cross-linking in the pipe.

Thus, the numerous warranty claims that NIBCO has denied solely due to excessive outer diameter, which NIBCO deemed to be indicative of exposure to excessive pressure, were denied without basis.

[55] ASTM F876-07, Table 2 Outside Diameters and Tolerances for PEX Tubing
[56] ASTM D2122-98 (2004), Sections 9.2.1 and 10.3 for measurements taken with a flat-anvil micrometer or Vernier caliper

NIBCO
AHEAD OF THE FLOW

LEBANON / FRANKLIN FACILITIES

STANDARD OPERATING PROCEDURE

DOCUMENT TITLE:

Dimensional Inspection

1/2" Blue PEX

Quality Assurance Dimensional Inspection

Date	Reel Number	Pre-Beamed: Plug Gage Go/No Go	Pre-Beamed: Max/Min. Wall	Pre-Beamed: Avg. Wall	Pre-Beamed: Max/Min. O.D.	Pre-Beamed: Avg. O.D.	Pre-Beamed: Out of Roundness	Q.C.	Post-Beamed: Plug Gage Go/No Go	Post-Beamed: Max/Min. Wall	Post-Beamed: Avg. Wall	Post-Beamed: Max/Min. O.D.	Post-Beamed: Avg. O.D.	Post-Beamed: Out of Roundness	Resin Lot Number	Print String Q.C.	Q.C.
9/25/09	FB04 217 1 09	✓	.075/.073	.074	.642/.618	.630	.024	df	✓	.076/.074	.075	.639/.621	.630*	.018	D81222328		df NP
↓	FB04 218 1 09	✓	.075/.073	.074	.640/.624	.632	.016	df		.075/.072	.074	.642/.619	.631*	.023	↓		NP
	FB04 219 1 09	✓	.075/.072	.074	.641/.623	.632	.018	df		.075/.073	.074	.642/.619	.631*	.023	D81222329		NP
	FB04 220 1 09	✓	.074/.073	.074	.639/.621	.630	.018	df		.075/.073	.074	.638/.624	.631*	.014	↓		NP
	FB04 221 1 09	✓	.074/.073	.074	.641/.621	.631	.020	df		.076/.073	.075	.640/.620	.630*	.020			NP
	FB04 222 1 09	✓	.075/.073	.074	.640/.620	.630	.020	df		.076/.074	.075	.636/.624	.630*	.012			NP
	FB04 223 1 09	✓	.074/.073	.074	.642/.622	.632	.020	df		.076/.074	.075	.637/.623	.630	.014			NP
* ↓	FB04 224 1 09	✓	.074/.072	.073	.641/.621	.631	.020	df		.075/.074	.075	.637/.617	.627	.020			NP
9/26/09	FB04 225 1 09	✓	.074/.073	.074	.640/.618	.629	.022	df	✓	.077/.075	.076	.643/.617	.630	.025			[signature]
	FB04 226 1 09	✓	.075/.073	.074	.634/.624	.629	.010	df	✓	.077/.075	.076	.643/.614	.629	.029			[signature]
	FB04 227 1 09	✓	.076/.074	.075	.635/.625	.630	.010	df		.075/.074	.075	.645/.617	.631*	.028			NP
↓	FB04 228 1 09	✓	.076/.074	.075	.643/.617	.630	.026	df		.076/.074	.075	.648/.604	.626	.044			NP

Comments: * Oversized OD within error of calipers NP 10/12/09

FB04226 – CRANBARRY

SOP QC-1003, Revision: B Effective Date: 7/1/08 QC Initials: NP

5 of 5

Paragon
POLYMER CONSULTANTS

Wall Thickness:

The vast majority of the examined pipes (all but approximately ten, out of 165) conformed to the wall thickness requirements of ASTM F876 and ASTM D2122.

Scanning Electron Microscopy (SEM) & Energy Dispersive X-ray Spectroscopy (EDS)

Select exposed fracture surfaces from incident cracks in the defective 1006 PEX pipe from the Cole and Meadow class actions were examined using a Scanning Electron Microscope (SEM) in the back-scattered electron imaging mode. Energy Dispersive X-ray Spectroscopy (EDS) was additionally used to more closely evaluate the crazing and/or brittle cracks observed at the interior surfaces of the pipes. This work remains in process, but preliminary images are presented in Appendix 10. The additional photo-documentation will be provided upon completion.

Results confirmed, as shown in Figures 14 through 16 that the incident PEX 1006 pipes failed due to oxidative degradation, which led to severe embrittlement and craze cracking at the interior surface of the pipe. Under conditions of constant hydrostatic pressure, these craze cracks easily propagated through the wall of the pipe due to the combined effects of oxidative degradation and creep rupture, thereby causing the pipe to leak. Extensive craze cracking with preferential growth in the longitudinal direction was observed near each cut edge of each incident pipe, suggesting that the PEX material was significantly embrittled by oxidation at the interior surface of the tubing.

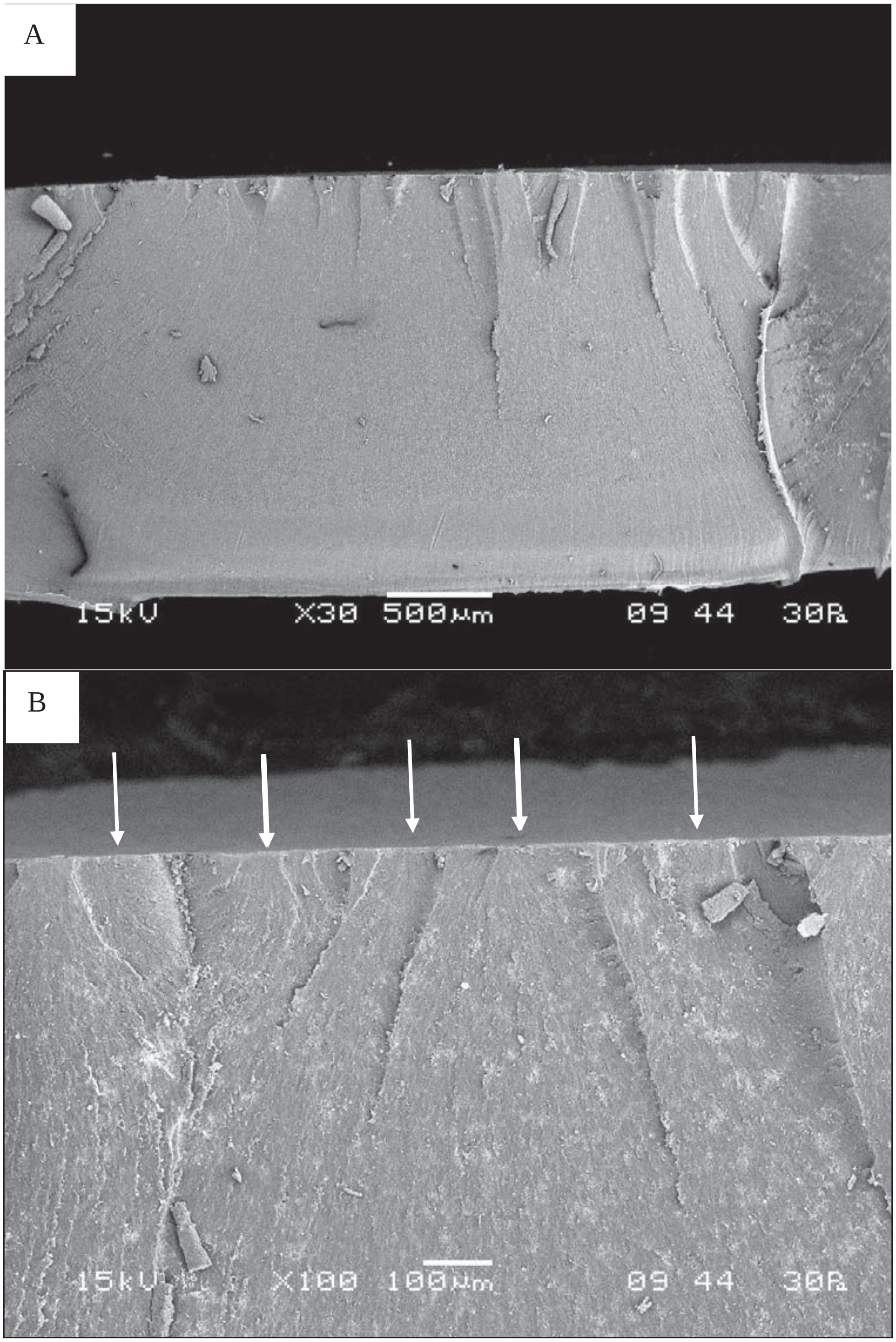


Figure 14: (A) Exposed fracture surface from McCoy Sample PPX-31, shown as viewed using a scanning electron microscope in the back-scattered electron imaging mode. This fracture initiated at the interior surface of the sample, at multiple locations as indicated by arrows in View (an adjacent region of fracture not depicted in View A).

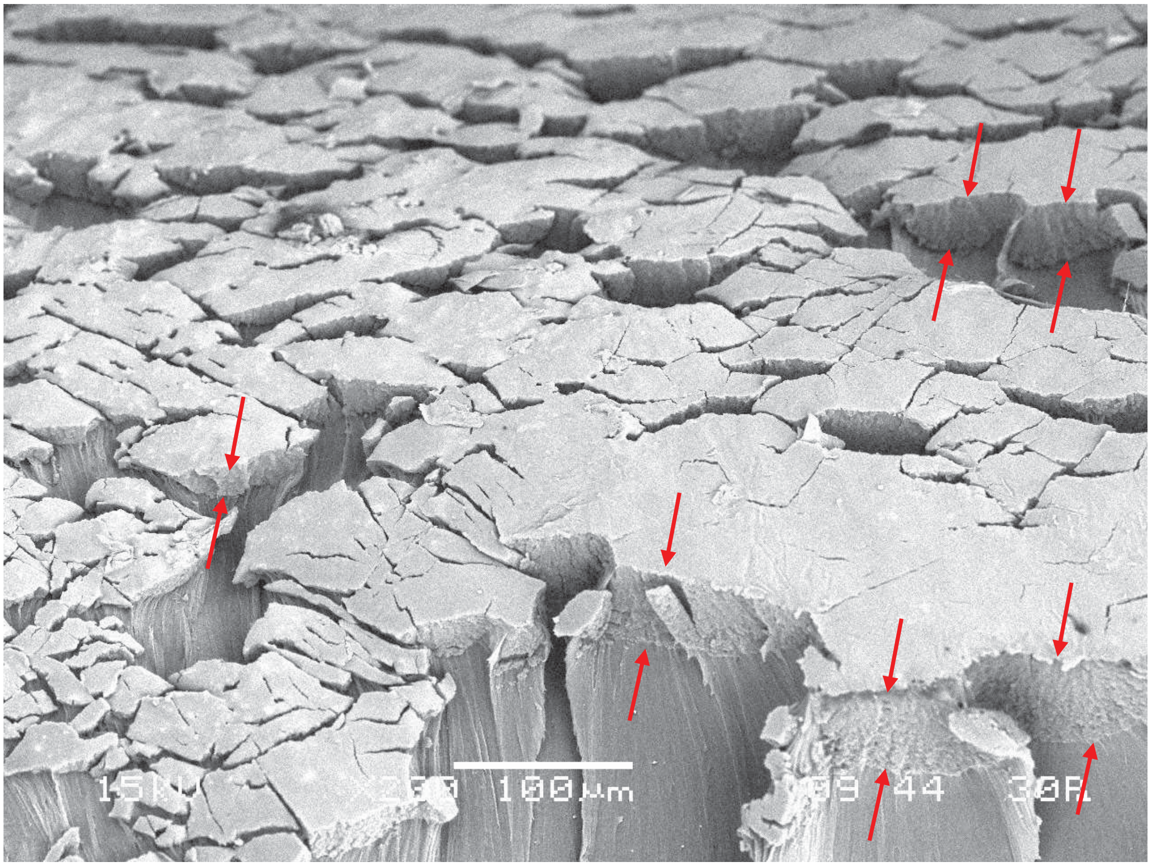


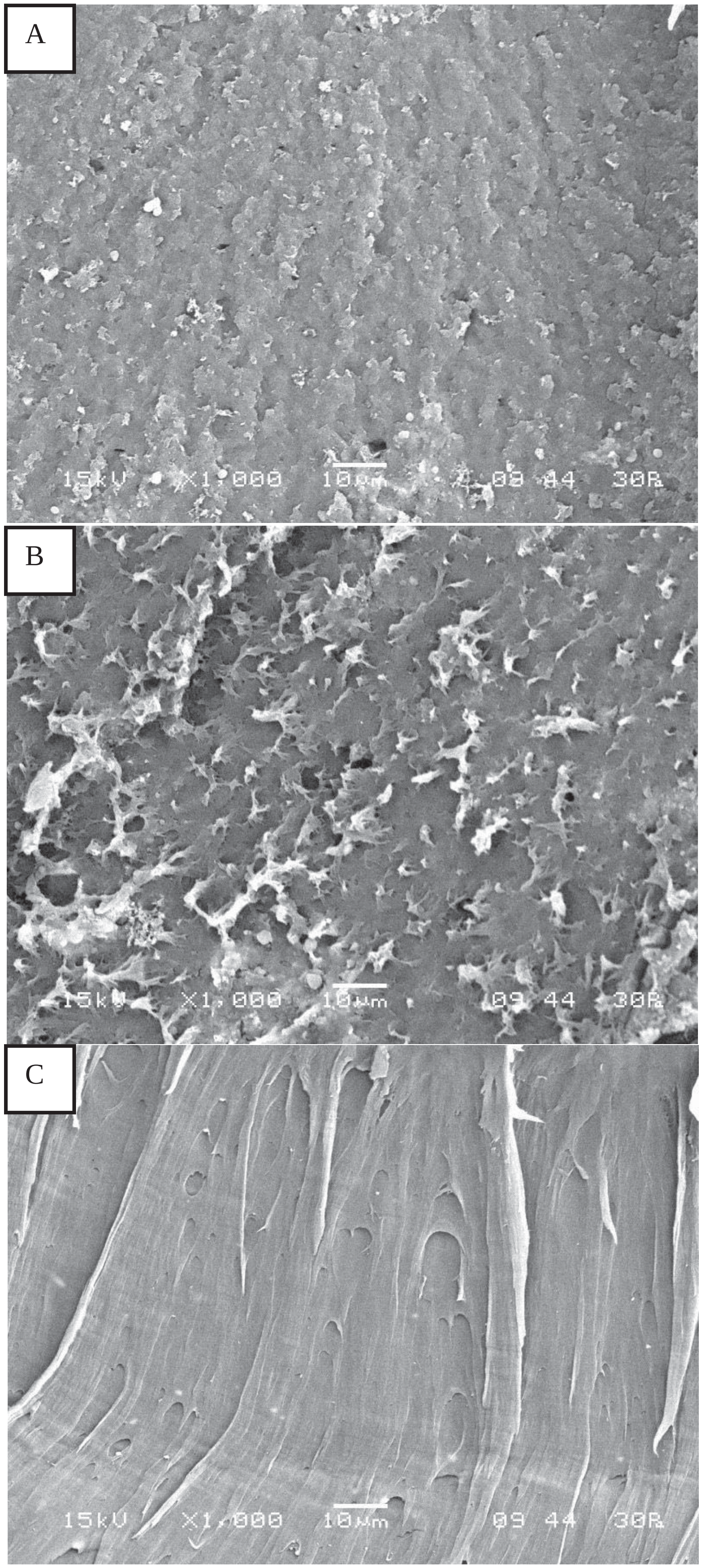
Figure 15: (A) Interior surface of McCoy Sample PPX-31, adjacent to the exposed fracture surface, where numerous craze cracks were revealed during bending to expose the fracture surfaces. This was essentially a modified bend-back test. These cracks clearly exhibited discernible depth as indicated by arrows.

Figure 16

Representative fracture features observed on the exposed fracture surface of McCoy Sample PPX-31 at:

(A) The initiation region adjacent to the interior surface of the pipe,
(B) The outer fracture region, just prior to lab-induced overload, and
(C) The lab-induced overload region.

The interior edge of the fracture exhibited features consistent with oxidative degradation of the PEX material, while the outer portion of the incident crack exhibited additional features consistent with creep rupture.



Fourier Transform Infrared Spectrometry (FTIR)

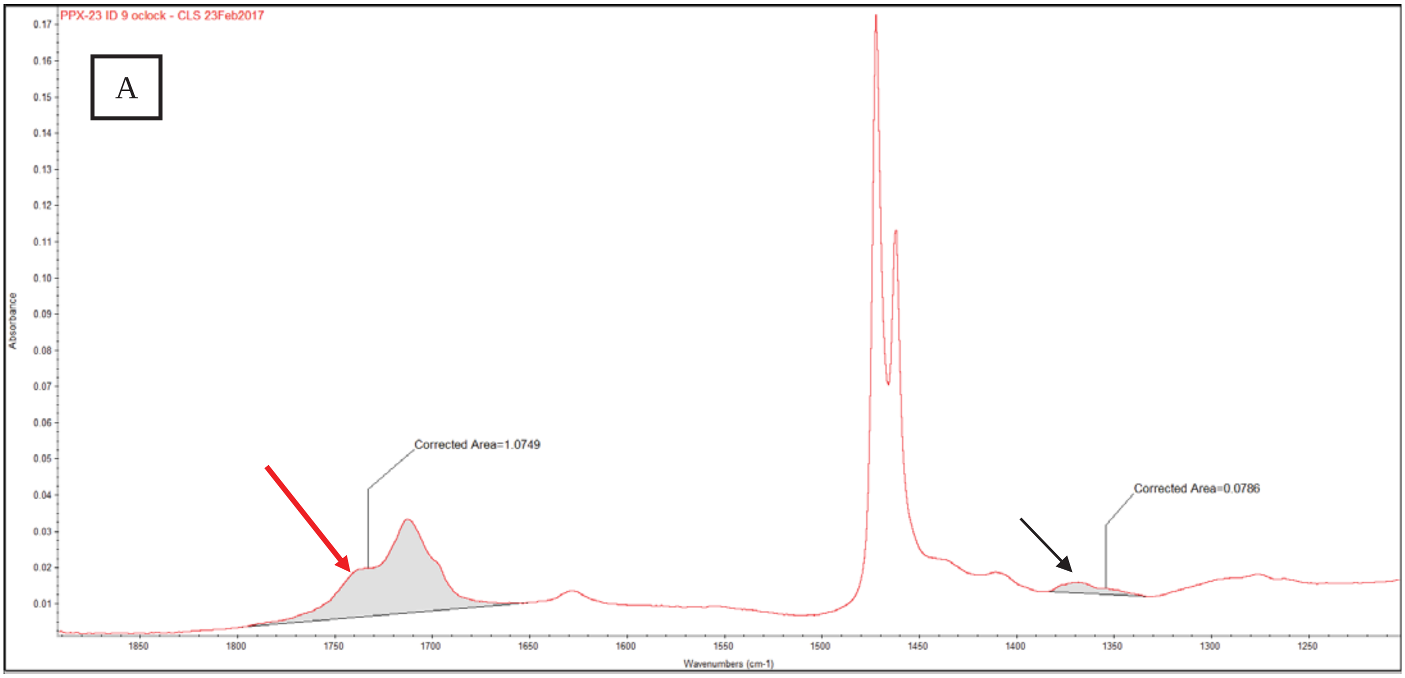
To evaluate the incident tubing for evidence of oxidative degradation, select pipe samples were analyzed at twelve locations each, by Fourier Transform Infrared Spectrometry (FTIR) in the attenuated total reflectance mode, in general accordance with ASTM F2102. Each sample was evaluated at 90 degree intervals around the pipe circumference (12 o'clock, 3 o'clock, 6 o'clock, and 9 o'clock), with the 12 o'clock position corresponding to the incident crack location. Within each 90-degree interval, the PEX material was evaluated at the interior surface (ID), the exterior surface (OD), and at approximately mid-wall (MID) so that the distribution of oxidation within the pipe wall could be analyzed.

Thin shavings of PEX material were excised from each area of interest using a clean, stainless-steel razor blade. The complete set of resulting FTIR spectra is contained in Appendix 11. An oxidation index was calculated for each area of interest in accordance with ASTM F2102, and results were then graphed to allow for semi-quantitative assessment of the oxidation distribution within the wall of the pipe.

The oxidation index (OI) is the ratio of the area of the carbonyl absorption bands ("peaks") centered near 1720 cm^{-1} to the area of the absorption bands ("peaks") centered near 1370 cm^{-1}. Each of these vibration bands ("peaks") is shaded in the representative spectrum shown in Figure 17 below, where it is seen that Cole Sample PPX-23 showed extensive oxidation at the interior surface of the pipe, but no detectable oxidation in the mid-wall region at the same pipe location.

An exemplar radar graph showing the results for Cole Sample PPX-23 is shown in Figure 18.

Detailed FTIR results are shown in Table 4 below, and the associated FTIR spectra and radar graphs are contained in Appendices 11 and 12, respectively.



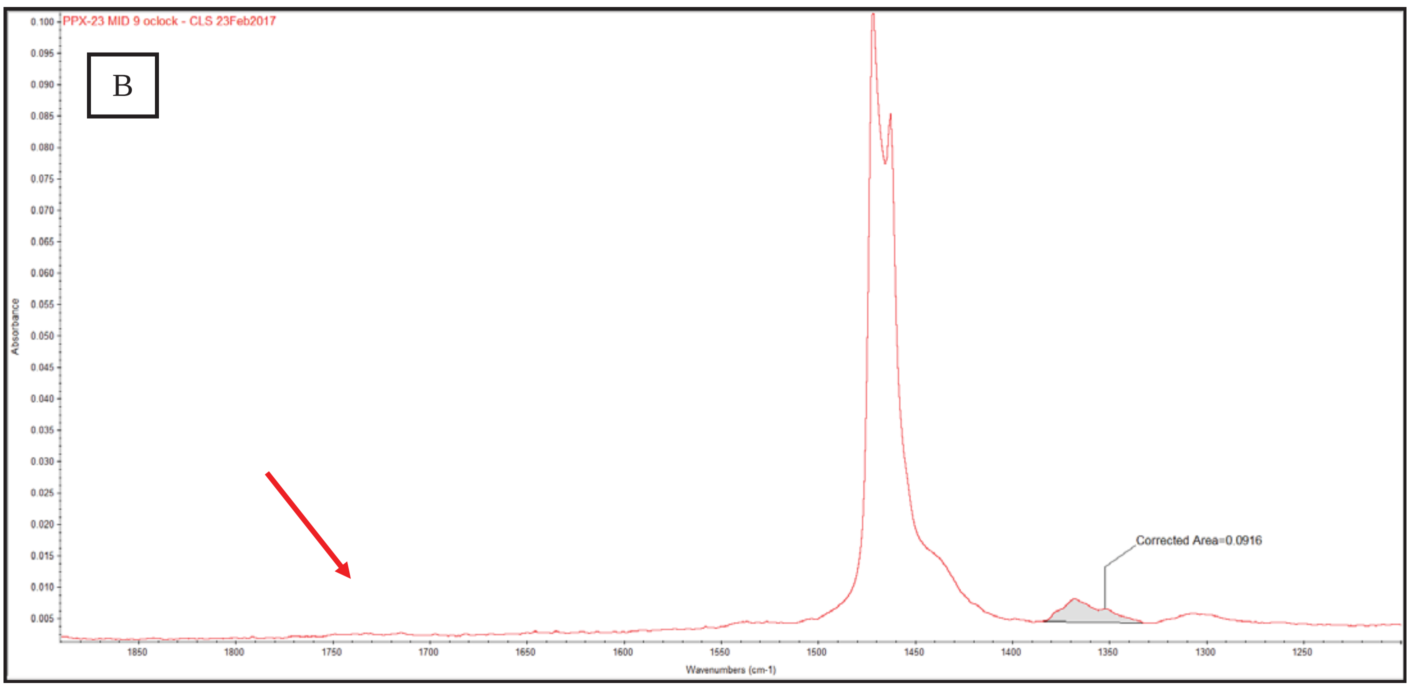


Figure 17: FTIR spectrum for Cole Sample PPX-23 (ID, 9 o'clock), showing appreciable oxidation at the interior surface of the pipe, as evidenced by the prominent carbonyl peak identified with a red arrow. The area of the carbonyl peak was normalized with the peak centered at 1370cm^{-1} (black arrow) to determine the carbonyl index. The carbonyl index at this location was 13.676. (B) In contrast, the mid-wall area of the same pipe at the 9 o'clock location revealed no detectable oxidation.

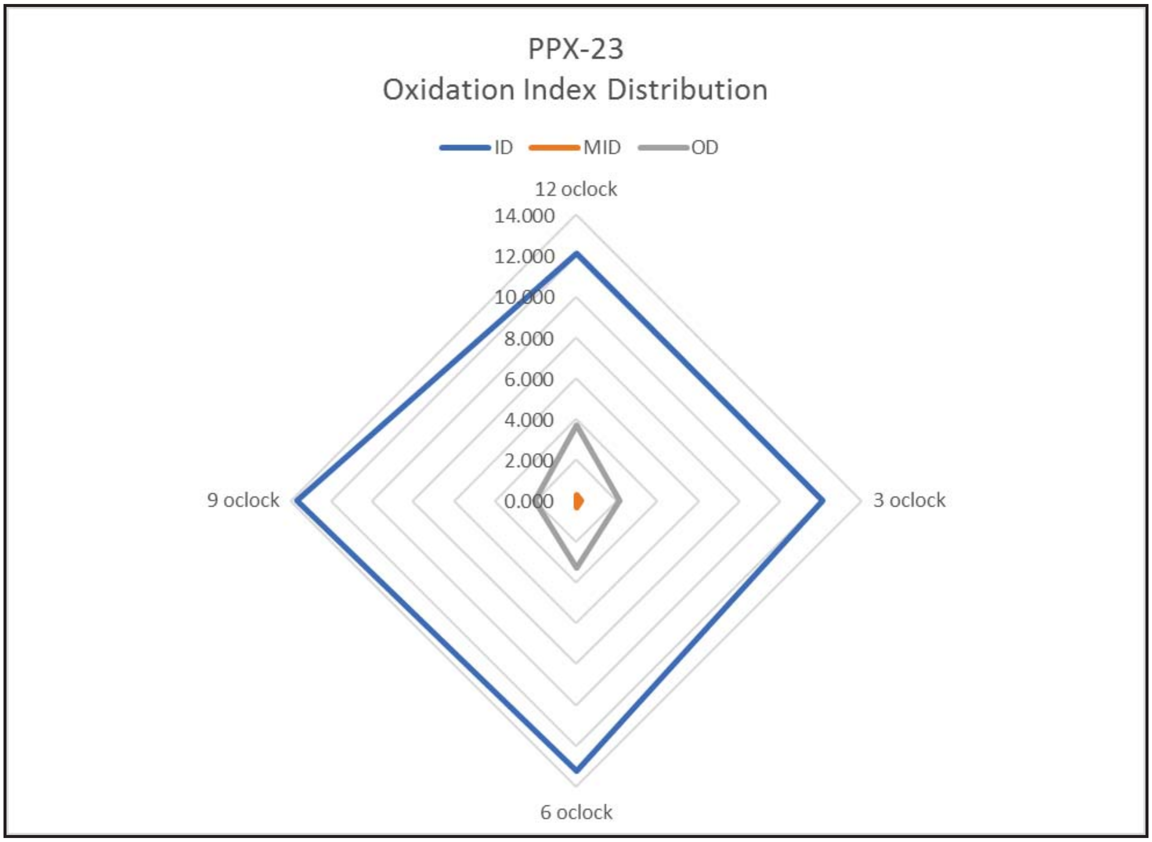


Figure 18: FTIR radar graph showing the oxidation index as a function of location within the pipe wall and around the pipe circumference for Cole Sample PPX-23. This sample showed significantly more oxidation at the interior surface than elsewhere in the pipe wall, around the entire pipe circumference. No evidence of UV damage was detected.

Table 4
Oxidation Index Determined by FTIR
(data continued to following pages)

Project 2016111 / 2013115 - Oxidation Evaluation by FTIR (Calculations Performed Per ASTM F2102-13)

Sample Name	Sample number	Sample Location - Midwall (MID), Adjacent to Outer Diameter (OD), or Adjacent to Inner Diameter (ID)	Circumferential Position (o'clock)	Oxidation Peak Area ~1720 cm^{-1} (OA)	Normalization Peak Area ~1370 cm^{-1} (NA)	Oxidation Index (OA/NA)
PPX-14 ID 12 o'clock	PPX-14	ID	12	0.3987	0.0574	6.946
PPX-14 ID 3 o'clock	PPX-14	ID	3	0.0527	0.0107	4.925
PPX-14 ID 6 o'clock	PPX-14	ID	6	0.3139	0.0514	6.107
PPX-14 ID 9 o'clock	PPX-14	ID	9	0.3180	0.0514	6.187
PPX-14 MID 12 o'clock	PPX-14	MID	12	0.0308	0.1393	0.221
PPX-14 MID 3 o'clock	PPX-14	MID	3	0.0000	0.1055	0.000
PPX-14 MID 6 o'clock	PPX-14	MID	6	0.0000	0.1264	0.000
PPX-14 MID 9 o'clock	PPX-14	MID	9	0.0375	0.1405	0.267
PPX-14 OD 12 o'clock	PPX-14	OD	12	0.4564	0.1077	4.238
PPX-14 OD 3 o'clock	PPX-14	OD	3	1.0779	0.0608	17.729
PPX-14 OD 6 o'clock	PPX-14	OD	6	0.9861	0.1132	8.711
PPX-14 OD 9 o'clock	PPX-14	OD	9	0.3760	0.1312	2.866
PPX-23 ID 12 o'clock	PPX-23	ID	12	0.9664	0.0799	12.095
PPX-23 ID 3 o'clock	PPX-23	ID	3	0.2796	0.0232	12.052
PPX-23 ID 6 o'clock	PPX-23	ID	6	1.1587	0.0874	13.257
PPX-23 ID 9 o'clock	PPX-23	ID	9	1.0749	0.0786	13.676
PPX-23 MD 12 o'clock	PPX-23	MID	12	0.0403	0.1296	0.311
PPX-23 MD 3 o'clock	PPX-23	MID	3	0.0355	0.1282	0.277
PPX-23 MD 6 o'clock	PPX-23	MID	6	0.0516	0.1527	0.338
PPX-23 MD 9 o'clock	PPX-23	MID	9	0.0000	0.0916	0.000
PPX-23 OD 12 o'clock	PPX-23	OD	12	0.5493	0.1479	3.714
PPX-23 OD 3 o'clock	PPX-23	OD	3	0.2661	0.1257	2.117
PPX-23 OD 6 o'clock	PPX-23	OD	6	0.4345	0.1318	3.297
PPX-23 OD 9 o'clock	PPX-23	OD	9	0.3095	0.1539	2.011
PPX-31 ID 12 o'clock	PPX-31	ID	12	1.0689	0.1091	9.797
PPX-31 ID 3 o'clock	PPX-31	ID	3	0.2897	0.0256	11.316
PPX-31 ID 6 o'clock	PPX-31	ID	6	1.3496	0.1348	10.012
PPX-31 ID 9 o'clock	PPX-31	ID	9	0.5358	0.0603	8.886

Table 4, continued
Oxidation Index Determined by FTIR

PPX-31 MID 12 o'clock	PPX-31	MID	12	0.0105	0.0823	0.128
PPX-31 MID 3 o'clock	PPX-31	MID	3	0.0305	0.0981	0.311
PPX-31 MID 6 o'clock	PPX-31	MID	6	0.0346	0.0990	0.349
PPX-31 MID 9 o'clock	PPX-31	MID	9	0.0277	0.0781	0.355
PPX-31 OD 12 o'clock	PPX-31	OD	12	0.2597	0.1266	2.051
PPX-31 OD 3 o'clock	PPX-31	OD	3	0.3124	0.1403	2.227
PPX-31 OD 6 o'clock	PPX-31	OD	6	0.3596	0.1356	2.652
PPX-31 OD 9 o'clock	PPX-31	OD	9	0.2614	0.1152	2.269
PPX-45 ID 12 o'clock	PPX-45	ID	12	0.3653	0.0446	8.191
PPX-45 ID 3 o'clock	PPX-45	ID	3	0.3072	0.0358	8.581
PPX-45 ID 6 o'clock	PPX-45	ID	6	0.5551	0.0490	11.329
PPX-45 ID 9 o'clock	PPX-45	ID	9	0.5435	0.0612	8.881
PPX-45 MID 12 o'clock	PPX-45	MID	12	0.0372	0.0818	0.455
PPX-45 MID 3 o'clock	PPX-45	MID	3	0.0184	0.1111	0.166
PPX-45 MID 6 o'clock	PPX-45	MID	6	0.0096	0.0774	0.124
PPX-45 MID 9 o'clock	PPX-45	MID	9	0.0221	0.1331	0.166
PPX-45 OD 12 o'clock	PPX-45	OD	12	0.3605	0.0916	3.936
PPX-45 OD 3 o'clock	PPX-45	OD	3	0.2101	0.0849	2.475
PPX-45 OD 6 o'clock	PPX-45	OD	6	0.5322	0.1129	4.714
PPX-45 OD 9 o'clock	PPX-45	OD	9	0.4143	0.1012	4.094
PPX-88 ID 12 o'clock	PPX-88	ID	12	0.2775	0.0543	5.110
PPX-88 ID 3 o'clock	PPX-88	ID	3	0.3793	0.0716	5.297
PPX-88 ID 6 o'clock	PPX-88	ID	6	0.3326	0.0653	5.093
PPX-88 ID 9 o'clock	PPX-88	ID	9	0.2951	0.0572	5.159
PPX-88 MID 12 o'clock	PPX-88	MID	12	0.0228	0.1048	0.218
PPX-88 MID 3 o'clock	PPX-88	MID	3	0.0330	0.1075	0.307
PPX-88 MID 6 o'clock	PPX-88	MID	6	0.0262	0.0877	0.299
PPX-88 MID 9 o'clock	PPX-88	MID	9	0.0366	0.1107	0.331
PPX-88 OD 12 o'clock	PPX-88	OD	12	0.5086	0.1205	4.221
PPX-88 OD 3 o'clock	PPX-88	OD	3	0.6814	0.0997	6.835
PPX-88 OD 6 o'clock	PPX-88	OD	6	0.3417	0.1420	2.406
PPX-88 OD 9 o'clock	PPX-88	OD	9	0.0288	0.1367	0.211
PPX-106 ID 12 o'clock	PPX-106	ID	12	0.0382	0.0112	3.411
PPX-106 ID 3 o'clock	PPX-106	ID	3	1.0785	0.0245	44.020
PPX-106 ID 6 o'clock	PPX-106	ID	6	0.7487	0.0279	26.835
PPX-106 ID 9 o'clock	PPX-106	ID	9	0.0000	0.1376	0.000
PPX-106 MID 12 o'clock	PPX-106	MID	12	0.0000	0.1159	0.000
PPX-106 MID 3 o'clock	PPX-106	MID	3	0.0000	0.0171	0.000

Table 4, continued
Oxidation Index Determined by FTIR

PPX-106 MID 6 o'clock	PPX-106	MID	6	0.0239	0.1156	0.207
PPX-106 MID 9 o'clock	PPX-106	MID	9	0.0000	0.1309	0.000
PPX-106 OD 12 o'clock	PPX-106	OD	12	0.1688	0.1159	1.456
PPX-106 OD 3 o'clock	PPX-106	OD	3	0.2845	0.1069	2.661
PPX-106 OD 6 o'clock	PPX-106	OD	6	0.3034	0.1412	2.149
PPX-106 OD 9 o'clock	PPX-106	OD	9	0.1631	0.1047	1.558
PPX-117 ID 12 o'clock	PPX-117	ID	12	0.1369	0.0239	5.728
PPX-117 ID 3 o'clock	PPX-117	ID	3	0.3249	0.0527	6.165
PPX-117 ID 6 o'clock	PPX-117	ID	6	0.0673	0.0105	6.410
PPX-117 ID 9 o'clock	PPX-117	ID	9	0.0264	0.0074	3.568
PPX-117 MID 12 o'clock	PPX-117	MID	12	0.0325	0.1089	0.298
PPX-117 MID 3 o'clock	PPX-117	MID	3	0.0000	0.0188	0.000
PPX-117 MID 6 o'clock	PPX-117	MID	6	0.0190	0.0838	0.227
PPX-117 MID 9 o'clock	PPX-117	MID	9	0.0845	0.0919	0.919
PPX-117 OD 12 o'clock	PPX-117	OD	12	0.0138	0.1306	0.106
PPX-117 OD 3 o'clock	PPX-117	OD	3	0.3806	0.1326	2.870
PPX-117 OD 6 o'clock	PPX-117	OD	6	0.2249	0.1328	1.694
PPX-117 OD 9 o'clock	PPX-117	OD	9	0.4818	0.1265	3.809
PPX-124 ID 12 o'clock	PPX-124	ID	12	0.9055	0.0920	9.842
PPX-124 ID 3 o'clock	PPX-124	ID	3	0.6852	0.0907	7.555
PPX-124 ID 6 o'clock	PPX-124	ID	6	0.8078	0.0814	9.924
PPX-124 ID 9 o'clock	PPX-124	ID	9	0.2990	0.0345	8.667
PPX-124 MID 12 o'clock	PPX-124	MID	12	0.0147	0.0538	0.273
PPX-124 MID 3 o'clock	PPX-124	MID	3	0.0241	0.0774	0.311
PPX-124 MID 6 o'clock	PPX-124	MID	6	0.0000	0.0091	0.000
PPX-124 MID 9 o'clock	PPX-124	MID	9	0.1991	0.0782	2.546
PPX-124 OD 12 o'clock	PPX-124	OD	12	0.2469	0.1235	1.999
PPX-124 OD 3 o'clock	PPX-124	OD	3	0.8889	0.1190	7.470
PPX-124 OD 6 o'clock	PPX-124	OD	6	0.1070	0.1026	1.043
PPX-124 OD 9 o'clock	PPX-124	OD	9	0.5062	0.0889	5.694
PPX-133 ID 12 o'clock	PPX-133	ID	12	0.2516	0.0445	5.654
PPX-133 ID 3 o'clock	PPX-133	ID	3	0.4486	0.0889	5.046
PPX-133 ID 6 o'clock	PPX-133	ID	6	0.3395	0.0640	5.305
PPX-133 ID 9 o'clock	PPX-133	ID	9	0.0719	0.0152	4.730
PPX-133 MID 12 o'clock	PPX-133	MID	12	0.0204	0.0723	0.282
PPX-133 MID 3 o'clock	PPX-133	MID	3	0.0234	0.0588	0.398
PPX-133 MID 6 o'clock	PPX-133	MID	6	0.0107	0.0722	0.148
PPX-133 MID 9 o'clock	PPX-133	MID	9	0.0104	0.1084	0.096

Table 4, continued
Oxidation Index Determined by FTIR

PPX-133 OD 12 o'clock	PPX-133	OD	12	0.6788	0.1181	5.747
PPX-133 OD 3 o'clock	PPX-133	OD	3	0.6298	0.1218	5.171
PPX-133 OD 6 o'clock	PPX-133	OD	6	0.5361	0.0745	7.196
PPX-133 OD 9 o'clock	PPX-133	OD	9	0.5206	0.1312	3.968
PPX-136 ID 12 o'clock	PPX-136	ID	12	0.3152	0.0664	4.747
PPX-136 ID 3 o'clock	PPX-136	ID	3	0.0526	0.0092	5.717
PPX-136 ID 6 o'clock	PPX-136	ID	6	0.4269	0.0824	5.181
PPX-136 ID 9 o'clock	PPX-136	ID	9	0.3354	0.0714	4.697
PPX-136 MID 12 o'clock	PPX-136	MID	12	0.0270	0.1275	0.212
PPX-136 MID 3 o'clock	PPX-136	MID	3	0.0286	0.1244	0.230
PPX-136 MID 6 o'clock	PPX-136	MID	6	0.0274	0.0579	0.473
PPX-136 MID 9 o'clock	PPX-136	MID	9	0.0233	0.1266	0.184
PPX-136 OD 12 o'clock	PPX-136	OD	12	0.3030	0.1115	2.717
PPX-136 OD 3 o'clock	PPX-136	OD	3	0.2843	0.1128	2.520
PPX-136 OD 6 o'clock	PPX-136	OD	6	0.2824	0.1012	2.791
PPX-136 OD 9 o'clock	PPX-136	OD	9	0.0328	0.0179	1.832
PPX-147 ID 12 o'clock	PPX-147	ID	12	0.3971	0.0838	4.739
PPX-147 ID 3 o'clock	PPX-147	ID	3	0.1182	0.0226	5.230
PPX-147 ID 6 o'clock	PPX-147	ID	6	0.3511	0.0804	4.367
PPX-147 ID 9 o'clock	PPX-147	ID	9	0.3919	0.0857	4.573
PPX-147 MID 12 o'clock	PPX-147	MID	12	0.0331	0.1304	0.254
PPX-147 MID 3 o'clock	PPX-147	MID	3	0.0111	0.0415	0.267
PPX-147 MID 6 o'clock	PPX-147	MID	6	0.0253	0.0969	0.261
PPX-147 MID 9 o'clock	PPX-147	MID	9	0.0000	0.0907	0.000
PPX-147 OD 12 o'clock	PPX-147	OD	12	0.3001	0.1343	2.235
PPX-147 OD 3 o'clock	PPX-147	OD	3	0.2601	0.1438	1.809
PPX-147 OD 6 o'clock	PPX-147	OD	6	0.3198	0.1462	2.187
PPX-147 OD 9 o'clock	PPX-147	OD	9	0.3522	0.1075	3.276

Each failed pipe consistently showed significant oxidation at the interior surface, with comparatively little or no evidence of oxidation at the exterior surface and/or mid-wall. This was consistent with the non-uniform levels of stabilization revealed by the Jana Laboratories, Inc. testing performed on behalf of NIBCO in 2009.[57]

The terra cotta pipe from the Plisko residence was found to be so severely oxidized that it was not possible to obtain a reliable FTIR spectrum. This particular pipe exhibited an extensive network of deep craze cracks that extended up to 25% into the pipe wall. These cracks caused interference with the infrared beam used for the FTIR analysis, resulting in a very jagged, irregular spectrum.

The high degree of oxidation detected at the interior surface of the incident pipes, coupled with significantly less oxidation at the exterior surface, indicated within a reasonable degree of scientific certainty that the pipe degradation was not appreciably influenced by ultraviolet radiation or an external heat source, but rather that the pipes consistently degraded preferentially at the interior surface (where the pipe was in contact with potable water) due to insufficient stabilization of the PEX material.

Oxidation Induction Time (OIT) Analysis

To evaluate the degree of *residual stabilization* of the PEX material at various locations in select tubing samples, a Netzsch Polyma DSC214 differential scanning calorimeter was used to measure the oxidation induction time (OIT) of prepared specimens in general accordance with ASTM D3895 – *Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry*.

Five samples of incident tubing have been evaluated to date, and additional test results are still pending. Each pipe was evaluated at 90-degree intervals around the pipe circumference (12 o'clock, 3 o'clock, 6 o'clock, and 9 o'clock positions), to assess the degree of residual stabilization adjacent to the interior surface (ID), exterior surface (OD), and at approximately mid-wall (MID). The 12 o'clock position coincided with the location of the incident crack.

Most of the incident samples showed virtually no residual stabilization at the interior surface, a moderate level of residual stabilization at the exterior surface of the pipe, and a comparatively high level of residual stabilization in the mid-wall region, similar to Medders Pipe Sample PPX-106 and Sminkey Pipe Sample PPX-46 (see graphs in Figure 19). The interior surface region generally oxidized in less than five minutes; the exterior surface region generally oxidized in 10-15 minutes; and the mid-wall region generally oxidized after 30-60 minutes.

The detailed OIT data for Medders Sample PPX-106 and Sminkey Sample PPX-46 is shown below in Table 5. A full summary of OIT testing completed to date for the

[57] NIBCO-Cole 00016181, CONFIDENTIAL – FOR ATTORNEYS EYES ONLY

Meadow and Cole class actions is contained in Appendix 13, and associated radar thermograms and graphs are contained in Appendices 14 and 15, respectively.

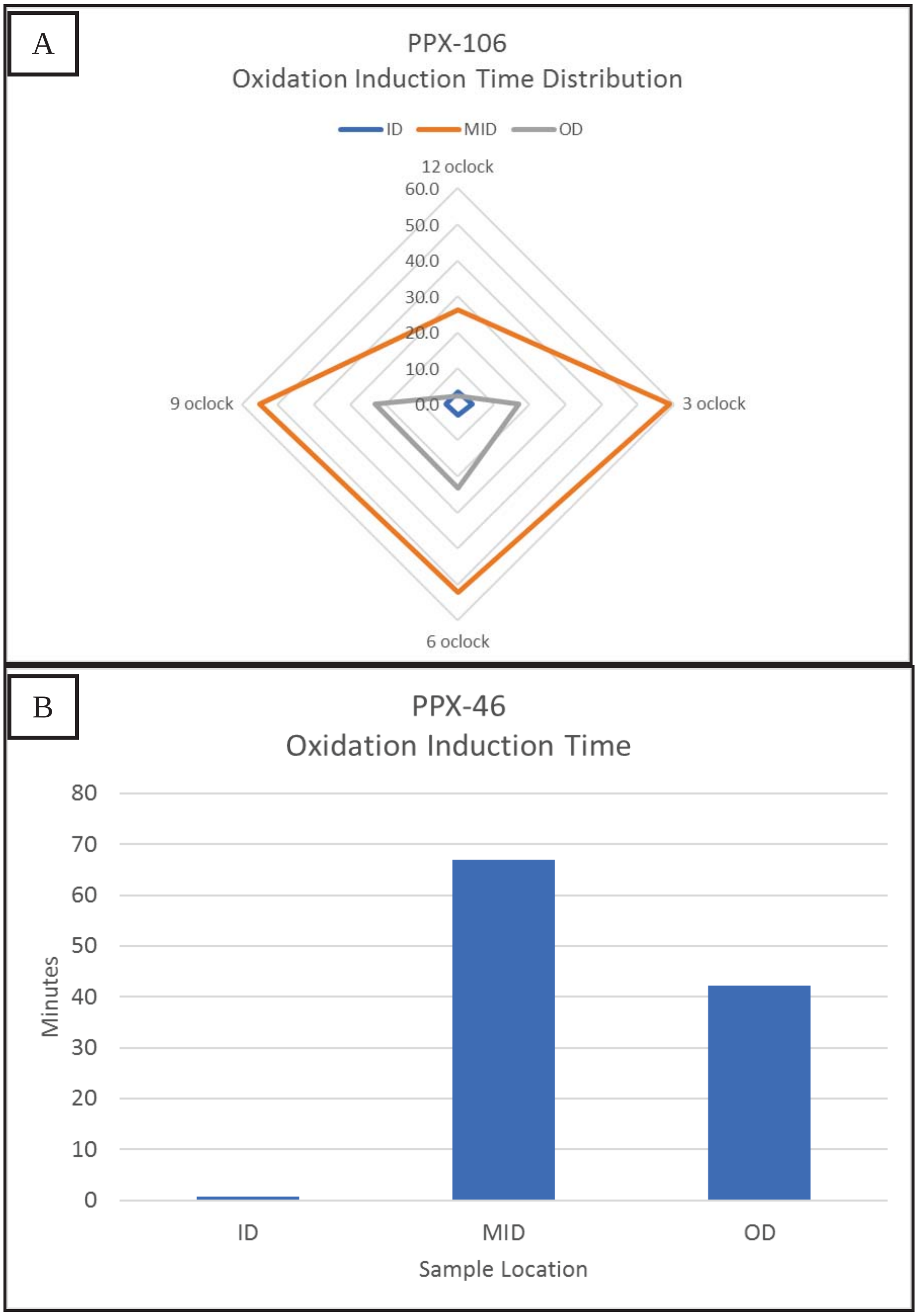


Figure 19: (A) Radar graph for Medders Sample PPX-106 depicting the oxidation induction time at various locations around the pipe circumference, and (B) Bar graph for Sminkey Sample PPX-46 (which was only tested at one circumferential location) depicting the oxidation induction time at various locations within the pipe wall. The OIT time was significantly lower at the interior surface of each pipe than at either the exterior surface or mid-wall. Patterns of non-uniform stabilization were detected in many samples, similar to the patterns of non-uniform stabilization that were detected by Jana Laboratories, Inc. for as-manufactured NIBCO 1006 PEX pipe.

Table 5
Oxidation Induction Time Determined by Differential Scanning Calorimetry for Medders Pipe PPX-106 and Sminkey Pipe PPX-46

Oxidation Evaluation by DSC – Medders PPX-106 and Sminkey PPX-46 (Calculations Performed Per ASTM 3895-07)

Sample Name	Sample storage location (box / ref)	Sample number	Sample Location - Mid-wall (MID), Adjacent to Outer Diameter (OD), or Adjacent to Inner Diameter (ID)	Circumferential Position (o'clock)	Oxidation Induction Time (OIT) min.
PPX-106 12 o'clock ID	1 / E1	PPX-106	ID	12	3.5
PPX-106 12 o'clock OD	1 / E2	PPX-106	OD	12	2.4
PPX-106 12 o'clock MID	1 / E3	PPX-106	MID	12	26.2
PPX-106 3 o'clock ID	1 / F1	PPX-106	ID	3	4.0
PPX-106 3 o'clock OD	1 / F2	PPX-106	OD	3	17.0
PPX-106 3 o'clock MID	1 / F3	PPX-106	MID	3	58.8
PPX-106 6 o'clock ID	1 / G1	PPX-106	ID	6	3.0
PPX-106 6 o'clock OD	1 / G2	PPX-106	OD	6	23.2
PPX-106 6 o'clock MID	1 / G3	PPX-106	MID	6	52.3
PPX-106 9 o'clock ID	1 / H1	PPX-106	ID	9	3.3
PPX-106 9 o'clock OD	1 / H2	PPX-106	OD	9	22.9
PPX-106 9 o'clock MID	1 / H3	PPX-106	MID	9	55.0
PPX-46 12 o'clock ID	2/E4	PPX-46	ID	12	0.8
PPX-46 12 o'clock MID	2/E5	PPX-46	MID	12	67
PPX-46 12 o'clock OD	2/E6	PPX-46	OD	12	42.3

These results are consistent with results obtained by Ms. Smith in past investigations related to NIBCO PEX 1006 pipe. They are also consistent with OIT results reported by Jana Laboratories, Inc. when evaluating NIBCO PEX 1006 field-returned pipe that was found to have failed due to brittle oxidative degradation. Further, these results are consistent with results reported by Total Petrochemical, indicating that there was no detectable antioxidant in any NIBCO or CPI PEX 1006 pipe sample that they evaluated on behalf of NIBCO.[58]

[58] TOTAL-Meadow 001272, CONFIDENTIAL

Most telling, these results are consistent with the OIT distribution patterns independently observed and reported by Jana Laboratories, Inc.[59] and Vanguard Material Sciences, LLC after evaluating pieces of never-installed NIBCO PEX 1006 pipe.[60]

The antioxidants that are intended to protect NIBCO PEX 1006 pipe were either non-uniformly distributed within the pipe wall and/or they were preferentially depleted at the interior surface of the pipe during manufacturing, leaving the pipe with insufficient stabilization to protect from oxidative degradation during service in a potable water environment.

NIBCO knew, or should have known, that its PEX 1006 pipe would not perform as intended in a typical potable water environment. Jana Laboratories, Inc. repeatedly alerted NIBCO to the deficiencies in this pipe, and Total Petrochemical, Inc. (supplier of the CD4300 resin used to manufacture NIBCO's defective PEX 1006 pipe) also advised NIBCO that it had detected virtually ***no*** antioxidant in any of the PEX pipes that NIBCO had sent to it for analysis.[61]

Past testing performed by Paragon Polymer Consulting, LLC and Vanguard Material Sciences, LLC demonstrated that never-installed tubing made from NIBCO's PEX 3308 formulation exhibited a roughly four-fold increase in Oxidation Induction Time in comparison to the never-installed PEX 1006 formulation.

Never-installed tubing made from the 3308 Formulation exhibited a mid-wall OIT of 432.4 minutes at the 12 o'clock position, while the never-installed 1006 formulation tubing exhibited a mid-wall OIT of only 186.9 minutes at the same location. This clearly demonstrated that the 3308 formulation was more highly stabilized, and thus, significantly more resistant to oxidative degradation, than the 1006 tubing formulation (consistent with empirical service history); although this result must be regarded as qualitative only. OIT is not well suited for quantitative comparison of products with different formulations.

Since these pipe samples had never been in service and no evidence of UV degradation was detected through FTIR analysis, the OIT measurements from this pipe were used to estimate the amount of OIT variation that may be expected around the tubing circumference for tubing that has never been in service. The OIT measurements varied as much as 60% around the tubing circumference, at a given test location within the tubing wall (ID surface, OD surface, or Mid-Wall). These results were consistent with data produced by NIBCO, showing significant variability in OIT performance (and by inference, significant variability in residual stabilization) within a single new NIBCO PEX 1006 pipe in the as-manufactured condition.[62]

---

[59] NIBCO-Cole 00016181 at 00016187 – CONFIDENTIAL, ATTORNEYS EYES ONLY
[60] NIBCO-Meadows 00128199 at 00128208 - CONFIDENTIAL
[61] Total-Meadow 001272 – CONFIDENTIAL
[62] NIBCO-Cole 00016181 at 00016187 – CONFIDENTIAL, ATTORNEYS EYES ONLY

Preliminary analysis of the OIT data for the incident pipes associated with the Meadow and Cole class actions revealed no atypical localized loss of stabilization that would suggest that excessive UV degradation or exposure to a localized heat source may have contributed to failure of the pipe. Additional OIT testing remains in process. Results will be provided upon completion of the analysis.

Gel Content Analysis

Eighteen representative pipe samples were evaluated in general accordance with ASTM D2765 – Method B (with the only deviations being the method of sample preparation as prescribed by ASTM F876 and the use of xylene) to determine the degree of cross-linking (the gel content) in the PEX material. NIBCO represented through labeling on the tubing and through marketing materials that the incident tubing conformed to the requirements of ASTM F876, which specifies that the PEX material must be at least 65% cross-linked. NIBCO also relied upon gel content testing in xylene when evaluating the gel content of as-manufactured NIBCO PEX 1006 tubing.

Of the 18 samples that were tested, four were found to be under-cross-linked as shown in Table 6. NIBCO knew (or should have known) that these pipes did not conform to the requirements of ASTM F876, and NIBCO knew (or should have known) that a tubing’s resistance to oxidative failure is closely related to the degree of cross-linking in the PEX material.

Table 6
Gel Content Analysis of NIBCO PEX 1006 Pipes

PPX #	Homeowner	Class Action/Project	Gel Content (% Crosslinked)	ASTM F876 Requirement (%)	Conformed to ASTM-F876?
PPX-105	Medders	Cole Named Plaintiff	65.0	65.0-68.0	(barely)
PPX-86	Peperno	Cole Named Plaintiff	67.3	65.0-68.0	YES
PPX-41	Lockett	Cole Class Member	67.7	65.0-68.0	YES
PPX-40	McCoy	Cole Named Plaintiff	68.3	65.0-68.0	YES
PPX-171	Cole	Cole Named Plaintiff	68.4	65.0-68.0	YES
PPX-13	Foley	Cole Class Member	67.3	65.0-68.0	YES
PPX-81A	McMahon	Cole Named Plaintiff	64.0	65.0-68.0	NO
PPX-46	Sminkey	Cole Named Plaintiff	70.6	65.0-68.0	YES
PPX-1	McCoy	Cole Named Plaintiff	70.4	65.0-68.0	YES
PPX-129	McLaughlin	Meadow Named Plaintiff	70.3	65.0-68.0	YES
PPX-39	Cole	Cole Named Plaintiff	66.2	65.0-68.0	YES
PPX-31	Cole	Cole Named Plaintiff	64.7	65.0-68.0	NO
PPX-116	Plisko	Meadow Named Plaintiff	66.8	65.0-68.0	YES
PPX-14	Burgos	Cole Class Member	61.0	65.0-68.0	NO
PPX-136	McLaughlin	Meadow Named Plaintiff	71.3	65.0-68.0	YES
PPX-116	Plisko	Meadow Named Plaintiff	67.7	65.0-68.0	YES
PPX-119	Plisko	Meadow Named Plaintiff	67.1	65.0-68.0	YES
PPX-136	McLaughlin	Meadow Named Plaintiff	71.4	65.0-68.0	YES
PPX-1	McCoy	Cole Named Plaintiff	72.5	65.0-68.0	YES
PPX-116	Plisko	Meadow Named Plaintiff	69.2	65.0-68.0	YES
PPX-116	Plisko	Meadow Named Plaintiff	69.1	65.0-68.0	YES
PPX-136	McLaughlin	Meadow Named Plaintiff	72.2	65.0-68.0	YES
PPX-1	McCoy	Cole Named Plaintiff	72.1	65.0-68.0	YES
PPX-136	McLaughlin	Meadow Named Plaintiff	72.1	65.0-68.0	YES
Never-installed tubing – PEX 1006 [63] (08/21/13-1, DR06-058-1-13)		NIBCO-Meadow	68.0	65.0-68.0	YES
Never-installed tubing -PEX 3308[64] (05/03/12-2, FRO6-086-4-12)		NIBCO-Meadow	67.6	65.0-68.0	YES

[63] NIBCO-Meadows 00128199 at 00128204 - CONFIDENTIAL
[64] NIBCO-Meadows 00128199 at 00128204 - CONFIDENTIAL

Water Chemistry Analysis

No evidence was found to suggest that atypical water chemistry or an atypical accumulation of surface deposits contributed to failure of the incident tubing. Water chemistry testing was performed both on-site and by Pace Analytical, a NELAP accredited water testing laboratory, for the 11 named plaintiffs' homes in the Cole and Meadow class actions in an effort to determine if there was something unusual about the water chemistry that may have caused these pipes to fail prematurely. The water chemistry was consistently found to be typical for potable water, with all tested parameters falling well within the expected ranges for potable water in the United States.

Detailed results of the water chemistry testing related to each named Plaintiff in the Meadow and Cole class actions are presented in Appendix 5.

Brass Fittings and Clamps

The incident brass fittings leaked due to through-wall dezincification corrosion and transgranular stress corrosion cracking (both of which are known to occur in brass alloys containing greater than 15% zinc). The incident *clamps* fractured due to transgranular chloride-induced stress corrosion cracking.

All NIBCO brass fittings and NIBCO stainless steel PEX clamps associated with the incident plumbing assemblies from each class action were visually inspected for evidence of corrosion and/or cracking, both with the unaided eye and with a research-grade stereomicroscope.

Visual inspection of the NIBCO brass fittings revealed ample evidence of "dezincification corrosion," which is a well-known dealloying mechanism that is widely addressed in published literature. When a brass fitting experiences dezincification corrosion, the zinc in the brass material selectively leaches into the water, leaving behind a porous, copper-rich structure that looks "spongy" when viewed with a microscope. Affected areas generally appear copper-colored and/or dark brown, (although they may also appear white or yellowish-white once the corroded surfaces become coated with zinc-oxide corrosion product and/or mineral deposits).

When brass fittings corrode in this manner, affected areas become weak and prone to fracture if any significant stress is placed on the fitting (as may occur through normal thermal expansion and contraction of PEX tubing that is attached to the outlets of the fitting). When a fitting has been weakened by through-wall dezincification corrosion, it can often be easily broken with bare hands. Monica and Medders each had fittings that were literally crumbling at the end of the outlet due to severe dezincification corrosion.

In addition to the dezincification corrosion, stereomicroscopic examination conducted at up to 40X magnification revealed multiple stress corrosion cracks initiating at the interior surfaces of at least two brass fittings, similar to the cracks shown in Figure 20. Stress corrosion cracking is a fracture mechanism that occurs when a susceptible metal is simultaneously exposed to static tensile stress (which can result from applied stresses and/or residual stress from manufacturing) and an incompatible chemical environment (in this case, the potable water).

Intact brass material from several different fittings, including some that had corroded appreciably and some that exhibited little or no apparent corrosion, was analyzed by Inductively Coupled Plasma Spectrometry with Atomic Emission Spectrometry (ICP-AES) to assess the composition of the brass alloys. Results revealed that each brass fitting was made from an alloy that contained greater than 36% zinc, indicating that these fittings were not suitable for the intended plumbing application.

The brass alloy designation and zinc content of each analyzed brass fitting is shown in Table 7. Detailed chemical analysis results are contained in Appendix 16.

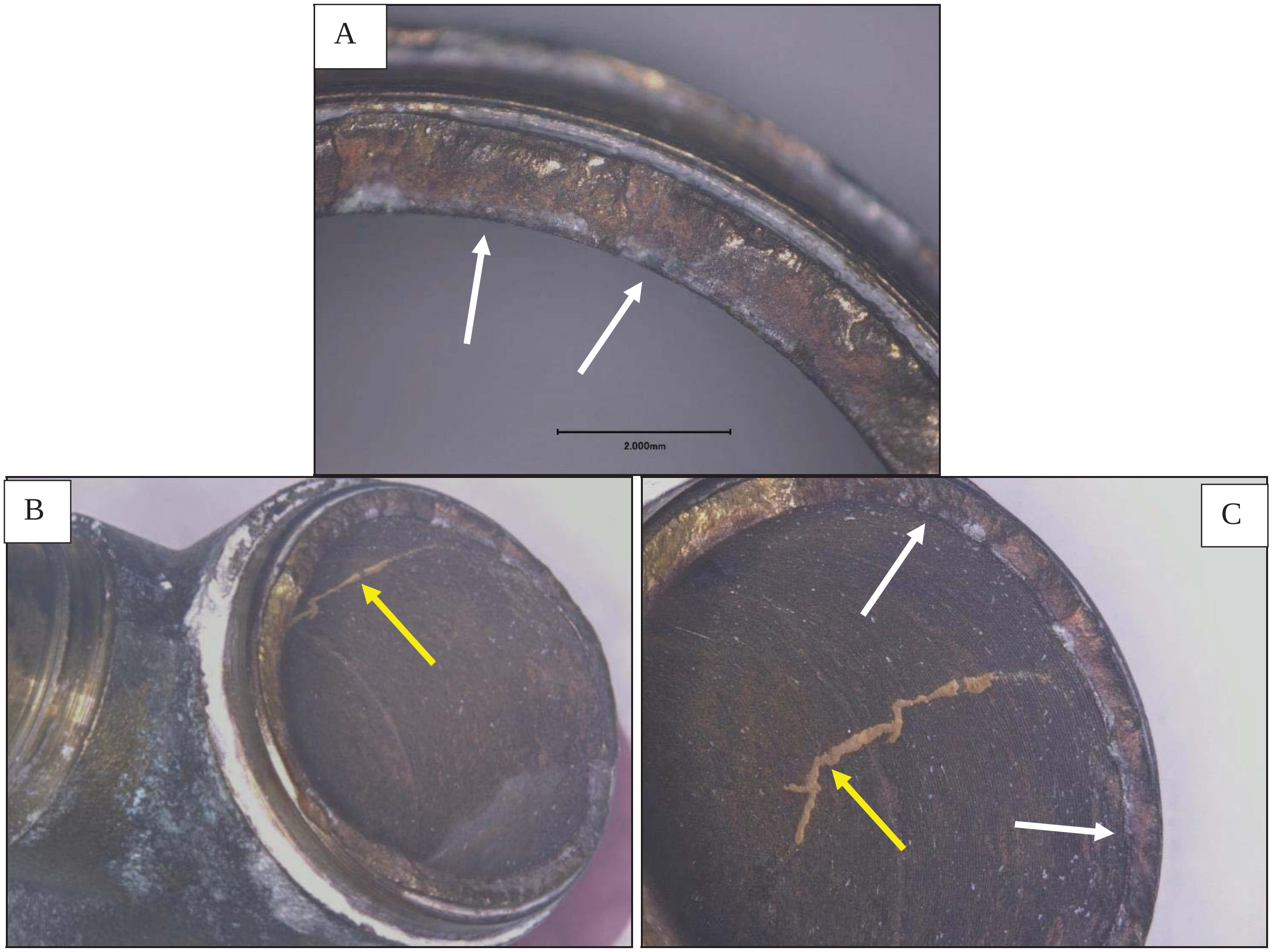


Figure: 20 Brass fitting from the Medders residence (PPX-99) that (A) fractured (white arrows) and (B, C) cracked (yellow arrows) due to stress corrosion cracking. Eventually, the stress corrosion cracks will penetrate the wall of the fitting, allowing water to leak through.

Table 7
Brass Alloy Designations and Zinc Content Determined by ICP-AES

Sample #	Closest Matching Alloy	Description	Zinc Content (w/o)
PPX-5	UNS-C-37700	forged yellow brass	38.06 %
PPX-16 Body	UNX-C-85700	cast leaded yellow brass	37.38%
PPX-91	UNS-C-85700	cast leaded yellow brass	37.4%
PPX-7 Body	UNS-C-37100	yellow brass	37.2%
PPX-90	UNS-C-85700	cast leaded yellow brass	36.70%

Select NIBCO stainless steel clamps were also evaluated by ICP-AES to assess the alloy chemistry. Each alloy was confirmed to be an austenitic stainless steel (see results in Appendix 16). Again, this is a design defect resulting from improper material selection for the intended application.

It is well established in published literature that austenitic stainless steels are susceptible to transgranular chloride-induced stress corrosion cracking at room temperature when simultaneously exposed to static tensile stress and concentrated chlorides.

Metallography

Metallographic examination of select fittings and clamps in the polished and etched conditions confirmed the failure mechanisms for the brass fittings and clamps. Through-wall dezincification in Monica brass fitting PPX-9 is shown in Figure 21. Extensive stress corrosion cracking in a stainless-steel clamp from Sample PPX-8 (Monica) is shown in Figure 22. Dezincification corrosion that had not yet penetrated through-wall in a brass fitting from Cole PPX-16 is shown in Figure 23.

When dezincification corrosion occurs, water will wick through the porous structure of the corroded brass fitting, wetting adjacent surfaces that would not normally be in contact with the water. When a NIBCO stainless steel clamp is used in conjunction with a corroded brass fitting, these chlorides can, in turn, lead to catastrophic failure of the clamp, allowing a high-volume release of water.

The stainless-steel clamp is used to seal the PEX tubing against raised sealing barbs on the outlet of the brass fitting. To achieve this seal, the clamp is tightened around the pipe until stresses in the clamp approach the tensile strength for the stainless-steel material (as evidence by "necking," or narrowing, that occurs near the windows of the clamp, as shown by the arrows in Figure 10C). When an austenitic stainless steel component is subjected to static tensile stress in the presence of chlorides, chloride-induced stress corrosion cracking may occur. The higher the stress in the stainless steel, and the more concentrated the chlorides, the greater the risk for failure. No evidence of

sensitization was detected in the incident clamps after electrolytically etching the polished cross-sections in 10% oxalic acid.

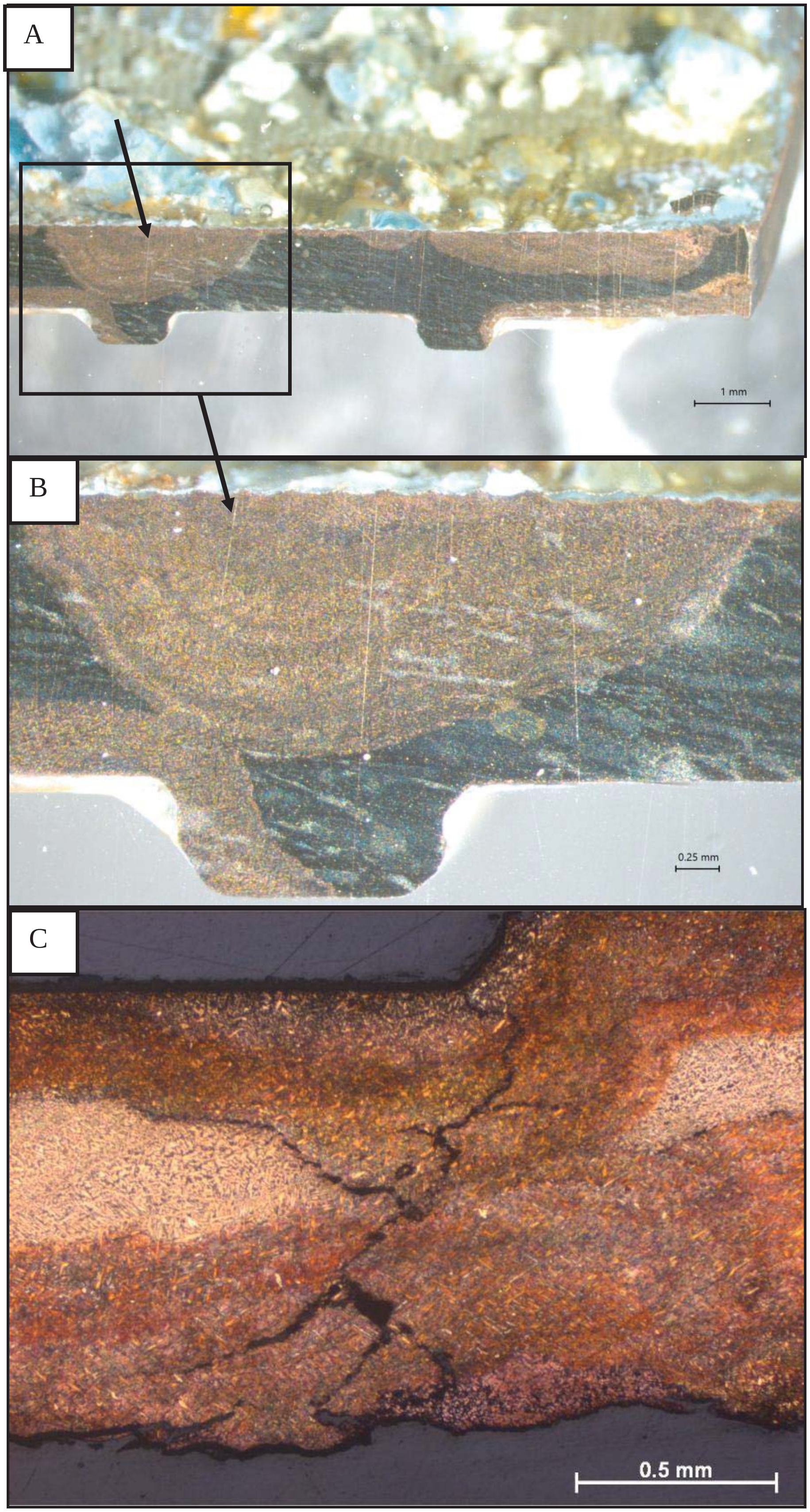


Figure 21:

(A, B) Coarsely polished cross-section through the wall of Monica Brass Fitting PPX-9, showing through-wall dezincification corrosion (arrows).

(C) Polished and etched metallographic cross-section through the wall of the same fitting, at a different location within the wall. Extensive crack was seen where the fitting had been weakened by through-wall dezincification.

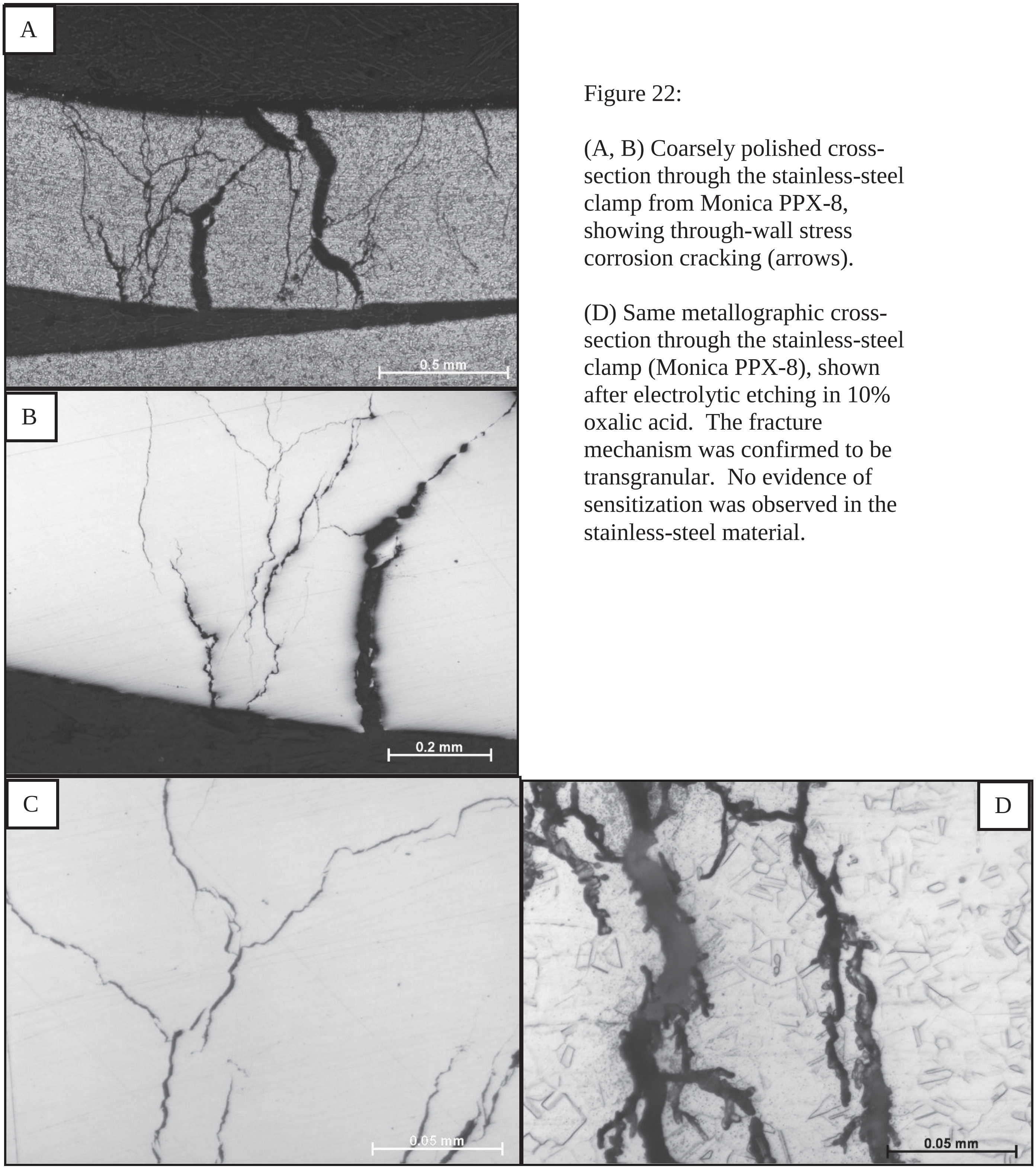


Figure 22:

(A, B) Coarsely polished cross-section through the stainless-steel clamp from Monica PPX-8, showing through-wall stress corrosion cracking (arrows).

(D) Same metallographic cross-section through the stainless-steel clamp (Monica PPX-8), shown after electrolytic etching in 10% oxalic acid. The fracture mechanism was confirmed to be transgranular. No evidence of sensitization was observed in the stainless-steel material.

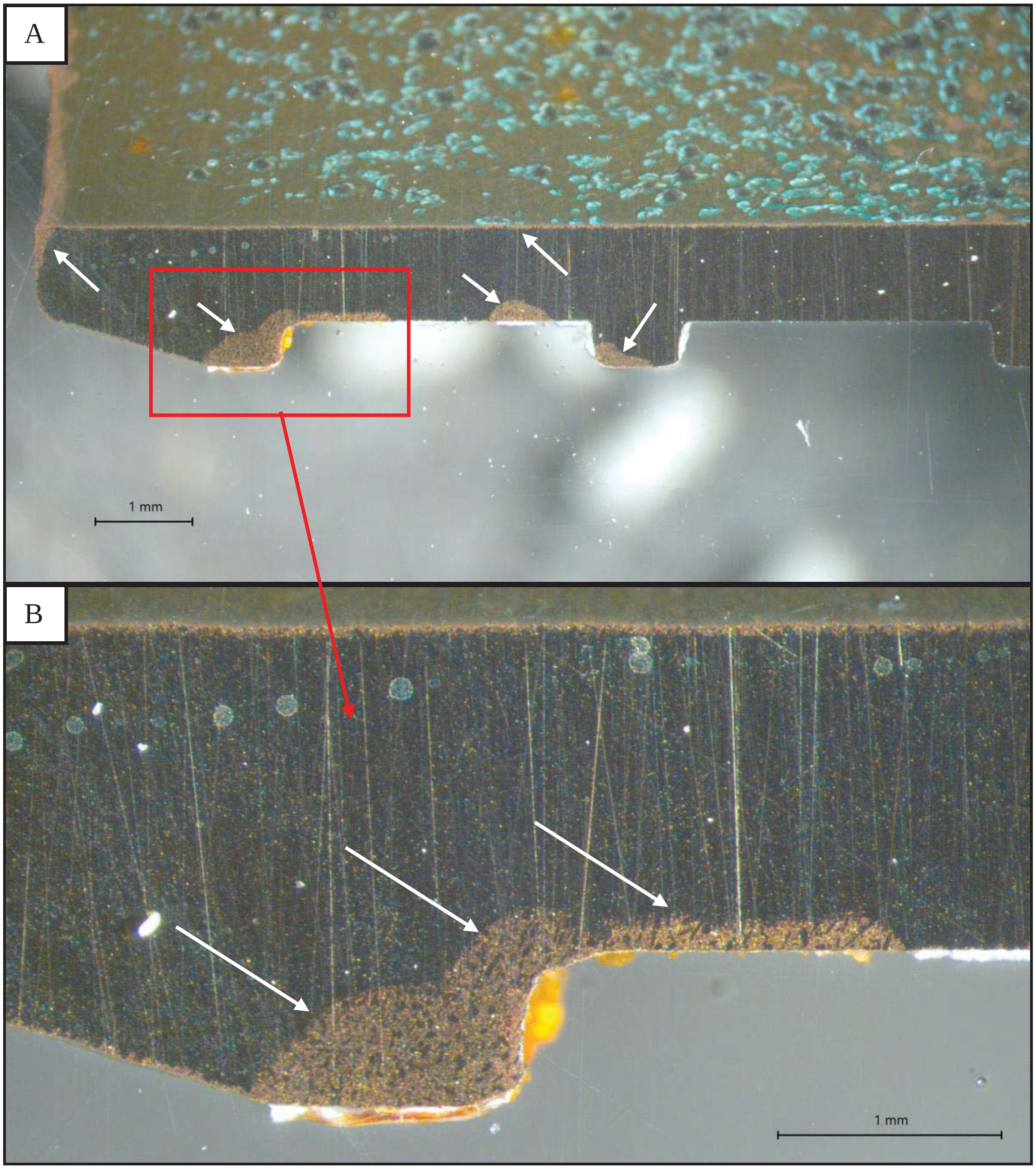


Figure 23: Coarsely-polished metallographic cross-section through the wall of the NIBCO brass fitting associated with Cole PPX-16, shown as viewed using a stereomicroscope. Evidence of dezincification corrosion (arrow) was noted at the exterior, end, and interior of the brass fitting (white arrows). Had the fitting been left in service, these corrosion fronts would have eventually grown through-wall, causing the fitting to leak. The Coles have experienced one fitting leak to date, but that fitting was not available for inspection.

All brass alloys containing greater than 15% zinc are universally susceptible to stress corrosion cracking and dezincification corrosion when placed in contact with potable water. Likewise, all NIBCO stainless steel PEX clamps (whether currently exhibiting signs of cracking or not) were found to be universally vulnerable to chloride-induced stress corrosion cracking if a source of chlorides is available.

Thus, all plumbing installations that utilize NIBCO yellow brass fittings and NIBCO stainless steel PEX clamps are vulnerable to premature failure due to these design defects. The rate at which these corrosion mechanisms penetrate the wall of the fittings and clamps can be highly variable, but stereomicroscopic examination revealed at least some degree of dezincification corrosion in nearly every NIBCO brass fitting examined.

Each failure mechanism is preventable, however, through proper material selection. Documentation produced by NIBCO demonstrated that NIBCO understood these failure mechanisms and how to prevent them; yet NIBCO neglected to take the necessary steps to ensure that their fittings and clamps would perform as intended in potable water environments.

Chlorides are one of the most abundant compounds on the planet, and they are commonly found in plumbing applications. If chloride-rich water seeps through a corroded brass fitting, allowing the adjacent stainless steel clamps to become continuously wetted with concentrated chlorides (which accumulate naturally through evaporation of leaking water), it is an almost certainty that the highly-stressed clamp will eventually fracture due to stress corrosion cracking. Some solder fluxes, concrete curing accelerants, flame retardants, and certain masonry materials that contain chlorides have also been shown to cause chloride-induced stress corrosion cracking in stainless steel PEX clamps.

SUMMARY OF OPINIONS

Based upon the efforts described above, Ms. Smith has formed the following opinions within a reasonable degree of scientific certainty:

1. The incident NIBCO PEX 1006 pipes leaked due to brittle cracks that initiated at the interior surface of the pipes due to oxidative degradation of the PEX material. The brittle cracks then propagated through-wall due to the combined effects of oxidative degradation and creep rupture (slow crack growth resulting from exposure to sustained hydrostatic stress).

2. The incident pipes consistently failed in a similar manner. Examination of:

    a. multiple incident pipes from homes that experienced multiple leaks in the same installation,
    b. incident pipes from 10 different states, 10 different water purveyors, and 10 different installers,
    c. pipe exposed to pressures above 80 psi versus pressures below 55 psi,
    d. hot water pipe versus cold water pipe, within a single home,
    e. pipe exposed to chlorinated water versus non-chlorinated well water,
    f. straight pipe versus curved pipe,
    g. ½" diameter pipe vs. ¾" diameter pipe vs. 1" diameter pipe, of the same color,
    h. red pipe vs. blue pipe vs. terra cotta pipe vs. white pipe, of the same size,
    i. pipe manufactured in 2006, 2007, 2008, 2009, 2010, and 2011,
    j. pipe from multiple homes in the same community, and
    k. pipes with date codes associated with multiple leaks vs. date codes associated with few leaks or no leaks in the same installation

    has consistently revealed evidence of oxidative degradation of the PEX material, with brittle cracks emanating from the interior surface of the tubing when cracks were observed. Even in a home where no leak had been reported, evidence of oxidative degradation and crazing (a network of fine, interconnected cracks) was observed, suggesting that impending brittle failure was likely.

    Jana Laboratories, Inc. also attributed similar brittle splits in field-returned pipe to oxidative degradation,[65] as did NIBCO.[66,67,68] Plastic Failure Labs reached a similar finding after investigating a rash of brittle oxidative failures that occurred in houses built by Pulte Homes in and around San Antonio, Texas.[69]

3. Within the past three (3) years, Ms. Smith has personally investigated over 900 plumbing leaks caused by brittle cracks in NIBCO 1006 PEX tubing, occurring

---

[65] NIBCO-Cole 00135173, Jana Laboratories Project 07-2173
[66] NIBCO-Cole 00134644, Email from Debbie Premus, dated 2/01/2011
[67] NIBCO-Cole 00135201, Email from Ken McCoy, dated 11/22/2010 – Confidential
[68] NIBCO-Cole 00062269 at 00062270
[69] NIBCO-Cole 00135075, Plastic Failure Labs Report, August 13, 2012

across North America (from Pennsylvania to Baja Mexico), including the pipes at issue in the class actions. Some of these cracks were oriented longitudinally in the wall of the tubing, while others were oriented circumferentially or at a 30°-45° angle relative to the longitudinal axis of the tubing.

4. These cracks formed slowly over time in typical residential potable water applications due to oxidative degradation of the PEX material resulting from insufficient design and insufficient stabilization for the intended application.

5. In many cases, evidence was found to indicate that a high level of residual stress in the PEX material from the designed manufacturing process contributed to crack initiation and/or propagation. The level of residual stress in the PEX material is determined by processing parameters during manufacturing, and is thus controlled by the tubing manufacturer through design and control of the manufacturing process. NIBCO knew (or should have known) that excessive residual stress in the PEX material could accelerate oxidative degradation of NIBCO PEX tubing, although excessive residual stress does not appear to be a necessary condition for oxidative failure to occur.

6. Localized stress concentrations at the interior surface of the tubing caused by linear extrusion defects further promoted crack initiation in many cases, although evidence indicates that this was not a necessary condition for failure to occur. Such extrusion defects, which form during manufacturing, are prohibited by ASTM F876. NIBCO knew (or should have known) that such defects could promote initiation of cracks in NIBCO PEX tubing, and they knew (or should have known) that pipes containing these defects did not conform to the requirements of ASTM F876. Thus, pipes containing these defects (which are readily detected through visual inspection with the unaided eye or a low-power microscope) should never have entered the stream of commerce.

7. In some cases, installation-related stresses may have influenced the rate of crack growth through the wall of the tubing and/or the location and orientation of through-wall cracks, but no evidence was found to indicate that improper installation caused the pipes to fail. None of the 165 plumbing components investigated in the Meadow and Cole class actions was excessively bent. Most of the leaks related to these cases occurred in relatively straight sections of tubing with no evidence of bend, crimp, rub, or other installation-related condition that would create an atypical stress condition in the wall of the tubing.

8. Craze cracking indicative of oxidative degradation and embrittlement of the PEX material was observed at the interior surface of nearly every incident pipe examined. Evidence indicates that these pipes were inherently under-designed and insufficiently stabilized for the intended application, and that they were destined to fail prematurely in contact with chlorinated water. In many cases, localized stress concentrations caused by manufacturing defects at the interior surface of the tubing and/or excessive residual stress in the tubing wall from manufacturing further promoted crack initiation and/or accelerated the failure

process, although localized stress concentrations are not necessary for failure to occur.

9. Despite the fact that NIBCO continuously marketed its PEX tubing as being "chlorine resistant" and compliant with ASTM F2023 (*Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water*), evidence indicates that NIBCO knew or should have known from the day it purchased CPI's assets in 2006 that the 1006 PEX formulation failed to exhibit adequate resistance to brittle oxidative failure when tested in accordance with ASTM F2023.[70,71]

10. NIBCO marketed its PEX pipe as being suitable for aggressive water applications: "NIBCO DURA-PEX pipe is corrosion resistant and can easily handle aggressive water conditions.[72]" Yet NIBCO has repeatedly denied warranty claims related to pin hole pipe leaks because NIBCO blames "aggressive water."

11. NIBCO knew (or should have known) that additional leaks would occur if tubing that had experienced a brittle oxidative failure remained in service. Yet, NIBCO prepared multiple claim denial letters related to leaks that occurred in the named Plaintiffs' residences, stating in some cases that the incident tubing was found to contain a "brittle split consistent with an oxidative-attack."[73] Knowing that Kimberly Cole had experienced 19 leaks as of November 30, 2016, NIBCO reportedly never recommended that the incident tubing be replaced to prevent additional damage. When replying to the Pliskos regarding their recurrent leaks, NIBCO wrote, "NIBCO never advises or considers compensation on removing products that are still performing in operation."[74] In homes where multiple failures occurred, the damages caused to the homeowners were unduly exacerbated by NIBCO's failure to advise that the tubing be replaced to prevent further damage to the residence.

12. NIBCO knew, or should have known, as of May 15, 2006 (the day that NIBCO reportedly acquired CPI's assets), that the 1006 PEX tubing formulation was insufficiently stabilized for the intended application, and that the tubing, brass fittings, and stainless steel clamps would not likely perform as advertised in plumbing applications, particularly where the tubing would be in contact with chlorinated water. However, NIBCO neglected to warn their customers regarding these design defects or to take steps to limit distribution of the defective products.

13. No evidence was found to suggest that NIBCO took any steps to limit distribution of the defectively designed tubing. Instead, NIBCO continued

[70] NIBCO-Cole 00135953-001355956, Confidential
[71] NIBCO-Cole 00015405-00015423, Confidential
[72] NIBCO- Cole 00012414, Confidential
[73] NIBCO-Meadows 00001435 at 00001436-00001438
[74] NIBCO-Meadows 00146552, 4/29/15 email from Kenneth McCoy – Confidential

manufacturing and selling tubing made from the 1006 formulation until all remaining inventory was consumed, even after the more highly stabilized 3308 PEX formulation (which was designed to provide greater resistance to oxidative failure) was in production.[75] Empirical evidence suggests that many pipe leaks could have been avoided if NIBCO had stopped producing the defectively formulated and insufficiently stabilized 1006 PEX pipe, and immediately switched to the redesigned PEX formulation and the resigned manufacturing process.[76]

14. NIBCO deliberately misrepresented the manufacturing date code on at least some 1006 PEX pipes. In July 2013, Earl Sexton (Engineering Manager for NIBCO) submitted Engineering Change Form 1423874[77] (see Figure 24) below, requesting that the print on all 1006 formulation PEX tubing made from that date forward be changed to falsely reflect a manufacturing date of <u>2/28/13</u>. This request was approved on 04/20/2013.[78] The Engineering Change Form suggests this was done to give the appearance that the tubing was manufactured during the time when the 1006 tubing formulation was still certified by NSF International, as the Universal Plumbing Code prohibited NIBCO from selling tubing that was not certified for use in potable water applications. Although NSF's certification of the 1006 formulation had already expired, NIBCO continued to manufacture and sell 1006 tubing until all 1006 material in inventory was consumed, even though NIBCO PEX 3308 was also in production at that time. A more robust design was available at the time this Engineering Change Form was issued. However, NIBCO chose not to halt production and distribution of the defective tubing (even while simultaneously manufacturing and distributing the more robust tubing to PEX 3308 customers), and opted to falsify the print string on the pipe to ensure that NIBCO was able to sell every last bit of the defective 1006 PEX formulation.

[75] Deposition of David Bobo, 2/2/17 at 198:23-25, 199:1-4, 199:9-25, 200:1-6,
[76] Deposition of David Bobo, 2/2/17 at 203:11-25, 204:1-7, 204:18-25, 205:1-2
[77] NIBCO Engineering Change Form #1423874 dated 03/05/2013, NIBCO-Cole 00047391
[78] NIBCO Engineering Change Form #1423874 dated 03/05/2013, NIBCO-Cole 00047391

NIBCO AHEAD OF THE FLOW®

ENGINEERING CHANGE FORM

1423874
ECR / ECN#

If you are receiving a **REQUEST**, please review, approve or reject, sign, and return to requestor.
If you are receiving a **NOTICE**, please review, take appropriate action, and file.

Written by:	SEXTONE
Date:(mm/dd/yy)	03/05/2013
Requested by:	*Debbie Premus*
Date: (mm/dd/yy)	*3/12/13*

(●) REQUEST
( ) NOTIFICATION

Reason for Change? *Use CTRL-Enter to create a line break between lines below.*

Lebanon SOP QC-1015 is to brand PEX with the date that it is cut, coiled and marked. This presents a challenge due to the termination of our NSF listing for PEX manufactured with Total HDPE. Any remaining Total WIP manufactured prior to termination of the listing but still requiring application of the NSF print stream, will need to be branded in a manner that indicates it was manufactured while the NSF listing was still active.

Description of Change: *Use CTRL-Enter to create a line break between lines below.*

Revise QC-1015 to specify that all remaining unmarked Total WIP (see inventory list in Supporting Documentation) is to be branded with a specified date (2/28/13) as near as possible to the last effective date of our NSF listing. This change will enable us to most closely approximate the date upon which this material is released to trade. THIS CHANGE APPLIES TO TOTAL WIP ONLY.

Items affected are: ☐ Purchased ☑ Manufactured

Change to: (Select all that apply) ☐ Vendor / Source ☐ Packaging ☐ Tooling ☐ Product Drawing ☑ Process ☐ Specification ☑ Quality Plan

Product Type: ☐ Plastic ☑ PEX ☐ Metal

Product Line: (Select all that apply) ☐ Balancing ☐ Check Valve ☐ Gate Valve ☐ Butterfly Valve ☐ Globe Valve ☐ Ball Valve ☐ DWV ☐ Chemtrol ☐ P & H ☐ Fire Protection ☐ Press ☐ Fittings ☑ DURA-PEX ☐ OEM ☐ Other

Affected Items: (Select all that apply) ☐ Fit/Form/Function ☑ Listed Product ☐ Submitted/Assembly Drawing ☐ Eng. Parts Book/Data System ☐ OEM Customer ☐ Material Master Data ☑ Tooling/Fixtures/Set-Up Card ☐ Test Gages/Fixtures ☐ Purchased Parts ☐ Product Catalog Data ☐ Online CAD Library ☐ Costs

☑ Inventory Affected: (Describe how to process existing inventory)

See inventory list in Supporting Documents: 10BPX, 10RPX, 10TPX, 08RPX, 03WPX, 03RPX, 03TPX, 02TPX, 02BPX

☐ Other (Please describe):

Routing:	*Name:*	*Initials:*	*Approve?*	*Reject?*	*Date:*
☐ Standards & Codes			○	○	
☐ Program Manager			○	○	
☐ Product Engineering			○	○	
☐ WHQ Engineering	sexton	ES	●	○	4/30/13
☐ Sales			○	○	
☐ Marketing			○	○	
☐ Purchasing			○	○	
☐ Tech Services			○	○	
☐ SAP Master Data			○	○	
☐ Quality			○	○	
☐ Mfg./Tooling Engineer			○	○	
☐ Plant Mngr.			○	○	
☐ Mfg. Plant	Debbie Premus	DP	●	○	4/30/13
☐ Mfg. Plant			○	○	

Released by:

Date: (mm/dd/yy)

Notes:

Distribute copies of this completed form for approval signatures.
Distribute revised documents to proper departments/locations.
Page 1

Figure 24: NIBCO continued to manufacture the defective 1006 PEX pipe even after the more-robust 3308 pipe was introduced[79], and went so far as to falsify the manufacturing date printed on the defective pipe so that it would appear that the pipe was manufactured before NIBCO's NSF listing expired. NIBCO was prohibited from selling pipe for potable water without certification. See NIBCO-Meadows 00047391.

[79] Deposition of David Bobo, 2/2/17 at 198:23-25, 199:1-4, 199:9-25, 200:1-6

15. Labeling on the incident tubing and documentation provided by NIBCO demonstrates that NIBCO intended for its product to conform to the requirements of ASTM F876, "*Standard Specification for Cross-Linked Polyethylene (PEX) Tubing.*" However, the average degree of cross-linking in approximately 22% of the eighteen failed pipes tested was found to be below the minimum degree of cross-linking required per ASTM F876. These eighteen evaluated pipes included samples from the Cole class action, the Meadow class action, and from Cole class members, as shown in Table 6.

    Thus, not all 1006 PEX pipe sold to the named Plaintiffs in the Meadow and Cole class actions conformed to the requirements of ASTM F876. NIBCO knew (or should have known) that the tubing did not conform to specification requirements, and this tubing should never have been sold by NIBCO. Resistance to oxidative degradation is directly influenced by the degree of cross-linking in the PEX material, with lower levels of cross-linking corresponding to decreased resistance to oxidative degradation and cracking. NIBCO was required to ensure that their pipe was adequately cross-linked, in accordance with ASTM F876.

16. The requirements of ASTM F876 state that the tubing "shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The tubing shall be as uniform as commercially practicable in color, opacity, density, and other physical properties." NIBCO recognized the importance of ensuring that the tubing be free of visible extrusion defects, as NIBCO's Product Specification PTS-091states on Page 6 of Appendix 8[80] that the tubing must be "free of any splay or surface imperfections from [the] extrusion process." Many of the failed pipes from the Cole and Meadow class actions exhibited pronounced longitudinal extrusion defects at the interior surface of the tubing. These extrusion defects created localized stress concentrations that further promoted crack initiation at the already insufficiently-stabilized interior surface of the pipe. Although cracking was also observed in samples that did not exhibit these longitudinal extrusion defects, evidence indicates that the extrusion defects offered preferential sites for crack initiation when such defects were present, thereby further shortening the life of the tubing. NIBCO knew (or should have known) that the incident pipes that contained extrusion defects did not conform to the requirements of ASTM F876, and these pipes should never have been sold. Although extrusion defects are not a necessary condition for oxidative degradation to occur, cracks tend to initiate earlier and grow through-wall more quickly when extrusion defects are present in the defectively designed and insufficiently stabilized pipe.

17. Additionally, the extrusion defects that accelerated failure of the tubing were preventable, and NIBCO had the knowledge and ability to easily detect these defects with nothing more than a visual inspection under a low power microscope. On December 14, 2012, Debbie Premus, Quality Manager for

[80] NIBCO-Cole 00037123 at 00037128

NIBCO, reported examining three pieces of tubing that had leaked during service due to oxidative cracking, and noted that the pipes contained "shallow grooves running along the entire interior length of the tubing, which is an extrusion defect…The extrusion defect may be a contributing factor in the case of this oxidative failure." [81]

At the time the incident pipes were manufactured, NIBCO had (or should have had) the ability to observe linear extrusion defects (sometimes called "die lines"), and NIBCO recognized (or should have recognized) extrusion lines as defects resulting from the extrusion process that could contribute to oxidative failure of the tubing. Given that ASTM F876 requires that PEX tubing be "homogeneous throughout and free of visible cracks, holes, foreign inclusions, and other defects," [82] pipes containing linear extrusion defects did not conform to the requirements of ASTM F876 and should not have been sold.

Although extrusion defects are not a necessary condition for oxidative degradation to occur, cracks tend to initiate earlier and grow through-wall more quickly when extrusion defects are present in the defectively designed and insufficiently stabilized pipe.

18. Approximately 66% of the pipes examined from the Meadow and Cole class actions exhibited an outer diameter (OD) that exceeded the maximum OD allowed per ASTM F876. Any time NIBCO has found an excessive outer diameter in field returned pipe exhibiting oxidative failure, NIBCO has attributed the excessive outer diameter to excessive pressure and/or temperature during service, and they have denied responsibility for the failures.[83,84,85] However, no evidence was found to suggest that excessive pressure and/or thermal expansion significantly contributed to failure for any of the incident pipes in either the Cole or Meadow class action, or that excessive temperature or pressure contributed to the excessive diameters.

Evidence indicates that these pipes were likely manufactured with an excessively large outer diameter. Reel after reel of NIBCO PEX tubing manufactured from 2006 through 2010 was routinely found to exhibit excessive outer diameters and to be excessively out-of-round, according to Quality Assurance Dimensional Inspection Records produced by NIBCO.[86] This was true for all colors and all

[81] NIBCO-Cole 00083208 - Notes for PER 2012120706
[82] ASTM F876-09 (*Standard Specification for Crosslinked Polyethylene (PEX) Tubing*) - Section 6.1
[83] NIBCO-Cole 00087986, Meadow PER Evaluation Response Letter
[84] NIBCO-Meadows 00001435 at 00001436, Peperno Customer Complaint Investigation Form dated 6/6/14
[85] NIBCO-Cole 00024659, NIBCO's PER Database (native file) – ATTORNEYS' EYES ONLY
[86] Reference NIBCO-Cole 00068913 at 00068935; 00068986; 00068987; 00069027; 00069075; 00069076; 00069107; 00069163 and NIBCO-Cole 00069365 at 00069412; 00069446; 00069473; 00069480; 00069481; 00069501; 00069505; 00069515 and NIBCO-Cole 00070654 at 00070669; 00070772; 00070836 for examples.

sizes of pipe. Exemplar dimensional inspection sheets showing these non-conforming conditions are contained in Appendix 9. In almost every instance of dimensional non-conformity, no evidence was found to indicate that pipes with excessive outer diameter were flagged or rejected by NIBCO due to the non-conforming condition, or that any steps were taken to correct the non-conforming condition. Thus, it is likely that NIBCO *sold* tubing that exhibited an excessively large outer diameter.

19. Many of the incident pipes and companion pipes examined from the Cole and Meadow class actions were also found to exhibit a greater degree of "out-of-roundness" than the maximum permitted by ASTM F876 for tubing in the pre-coiled condition (reference dimensional inspection records in Appendix 9). Although the incident tubing was no longer in the pre-coiled condition at the time the tubing was measured, extensive review of Quality Assurance Dimensional Inspection Records produced by NIBCO revealed that it is reasonably probable that some or all of those pipes were excessively out-of-round prior to coiling. NIBCO's dimensional inspection records revealed that most NIBCO PEX 1006 pipe manufactured from 2006 through 2012 was excessively out-of-round before and/or after the E-beam process, and prior to final coiling[87]. No evidence was found to indicate that tubing was typically (if ever) rejected for excessive out-of-roundness, even when the degree of out-of-roundness was more than four-times the permitted maximum. Tubing was occasionally rejected for other non-conforming conditions, but pipes with excessive out-of-roundness were not rejected even on the same test report. Thus, it is reasonably probable that NIBCO allowed tubing that did not conform to ASTM F876 due to excessive out-of-roundness to enter the stream of commerce. These pipes should never have been sold. Although an out-of-round condition is not necessary for brittle oxidative failure to occur, cracks tend to initiate earlier in out-of-round pipe due to localized stress concentrations created by the out-of-round condition.

20. No evidence was found to suggest that over-pressurization, excessive water temperature, excessive UV exposure, or atypical water chemistry contributed significantly to failure of the incident tubing in any of the pipes investigated from the Cole and Meadow class actions.

21. No evidence was found to suggest that improper installation, excessive bending, freezing, misuse, or abuse caused the incident pipes to fail. Although in some cases, the manner of installation may have created localized stress concentrations that influenced the *orientation* of the cracks and/or the *rate* of crack growth for nearby cracks, pervasive evidence of oxidative failure was observed throughout the pipes examined after contact with chlorinated water, without regard for the

[87] Reference NIBCO-Cole 00068913 at 00068935; 00068986; 00068987; 00069027; 00069075; 00069076; 00069107; 00069163 and NIBCO-Cole 00069365 at 00069412; 00069446; 00069473; 00069480; 00069481; 00069501; 00069505; 00069515 and NIBCO-Cole 00070654 at 00070669; 00070772; 00070836 for examples.

manner of installation. NIBCO has consistently asserted that "environmental factors" including "pressure, thermal expansion, bend stress, etc." contributed to the oxidative attack (particularly when the crack was located at a bend in the tubing, when the outer diameter of the tubing exceeded the maximum permitted by ASTM F876, and/or when elevated pressure was documented or suspected based upon the absence of a PRV or expansion tank)[88]. However, evidence indicates otherwise. Neither the number of failures experienced in a given home, nor the time to failure, was found to consistently correlate with temperature, pressure, the use of pressure reducing valves, or to the manner of installation for the incident tubing (neither to the degree of bend nor to the presence or absence of crimps, rub, and/or deformation).

22. Were it not for the fact that the NIBCO PEX 1006 pipe was insufficiently formulated and insufficiently stabilized for the intended application, the tubing installed in the named Plaintiff's homes would not have failed in the manner that it did.

23. NIBCO knew (or should have known) that the incident tubing exhibited insufficient resistance to chlorine and that the tubing was likely to fail prematurely in the intended application. From the day NIBCO acquired CPI's assets in 2006, NIBCO knew (or should have known) that red and orange CPI PEX pipes (which were manufactured using the same formulation, same processing equipment, and same processing parameters used for NIBCO's 1006 PEX pipe) had failed chlorine resistance testing performed in accordance with ASTM F2023 as required by ASTM F876. NIBCO PEX pipe was required to successfully pass this test in subsequent sampling to maintain NSF International's certification of NIBCO PEX pipe, and numerous documents produced by NIBCO indicate that NIBCO believed that the 1006 formulation would not likely pass this test.[89]

24. Safer alternative designs that met or exceeded the minimum chlorine resistance requirements of ASTM F876 and ASTM F2023 were commercially available at the time NIBCO manufactured the incident tubing (and in fact, NIBCO's competitors were using these more highly stabilized formulations to manufacture PEX tubing in 2006, when NIBCO initially purchased CPI's assets). However, NIBCO continued to manufacture the defectively designed and insufficiently stabilized pipe for at least six (6) years after becoming aware of the tubing's vulnerability to chlorine (on the day NIBCO purchased CPI's assets) and before introducing a more robust tubing formulation in the latter half of 2012. If NIBCO had used a formulation that was suitably resistant to oxidative degradation in potable water applications, the pipes in the homes of the named Plaintiffs and class members would not have failed in the manner that it did, and the damages incurred by the named Plaintiffs in the Cole and Meadow class actions could have been avoided.

[88] NIBCO-Cole 00024659 – NIBCO's PER Database – ATTORNEYS' EYES ONLY
[89] NIBCO-Cole 00015405

25. The design defects that existed in the incident NIBCO PEX tubing (improper material selection, coupled with defective design of manufacturing leading to insufficient stabilization for the intended application) were the cause of damages incurred by the named Plaintiffs in the Cole and Meadow class actions and the Cole proposed class members. Various manufacturing defects (non-conforming dimensions, die lines, extrusion defects, inclusions, etc.) further promoted crack initiation in the insufficiently stabilized tubing; however, the presence of a manufacturing defect was not required for oxidative failure to occur because the fundamental design of the 1006 PEX tubing was inadequate.

26. Documentation produced in this case reveals that NIBCO reformulated its PEX tubing because the 1006 PEX formulation failed to consistently exhibit adequate resistance to oxidative degradation when tested in accordance with ASTM F2023 (*Standard Test Method for Evaluating the Oxidative Resistance of Cross-linked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water),* thereby jeopardizing NSF International's certification of NIBCO PEX tubing and NIBCO's market-share in the PEX industry.[90,91,92,93] NIBCO chose to quietly introduce the reformulated 3308 PEX product, and to delay widespread production of the 3308 PEX pipe until all resin for the defective PEX 1006 had been consumed.

[90] NIBCO-Cole 00015405 – Confidential - PEX Development Strategy Executive Review, 2/9/2009
[91] NIBCO-Cole 00047339 - NIBCO Engineering Change Form 1400671, 12/21/2009
[92] JANA-000001 at JANA-000053 – Confidential - email from Gary Wilson
[93] JANA-000001 at JANA-000051-000052 – Confidential – JANA email thread dated 12/12/2010

CONCLUSION

Evidence indicates that NIBCO's PEX plumbing products are defectively designed and likely to fail prematurely during service, as:

A. All CPI and NIBCO PEX 1006 plumbing pipe manufactured on or after May 15, 2006 (and possibly earlier), is inherently defective due to improper material selection and defective manufacturing design, which renders the pipe insufficiently stabilized for the intended application. These pipes may fail in as little as 1-2 years after installation, and typically experience recurrent plumbing leaks until the plumbing system is replaced. Excessive temperature and pressure can accelerate the failure process, but empirical evidence has shown that even cold water systems with pressures below 50 psi (well below the 80-psi maximum that the pipe is rated for) have failed due to oxidative degradation. This is true for all sizes and colors of NIBCO PEX 1006 pipe.

B. All CPI and NIBCO brass PEX plumbing fittings are defective in their design due to improper material selection. Because these fittings are made from brass alloys containing greater than 15% zinc, they are universally susceptible to premature failure due to dezincification corrosion and/or stress corrosion cracking. When failure occurs by either mechanism, the fittings allow water to weep through the wall of the fitting, leading to water damage and mold over time, or the fitting can break in two causing a potentially catastrophic loss of water.

C. All NIBCO Stainless Steel PEX clamps are defective in their design, due to improper material selection. The highly-stressed clamps are inherently vulnerable to stress corrosion cracking in the presence of chlorides. Chlorides are commonly encountered in potable water applications.

In some cases, installation-related stresses may influence the *rate* of crack growth through the wall of the tubing and/or the *location and orientation* of through-wall cracks, but the inherent design defects in the NIBCO PEX 1006 have caused recurrent failures to occur even when the tubing is correctly installed. Numerous leaks have occurred in straight sections of tubing with no evidence of bend, crimp, rub, or other installation-related condition that would be expected to augment stresses in the pipe wall.

Evidence indicates that these plumbing components were universally defective in design, and that they are unsuitable for plumbing applications, particularly those utilizing chlorinated water.

RESERVATION OF RIGHT TO AMEND

The opinions rendered in this report are based upon site inspections, examination of the physical evidence, and information available at the time the report was written. Ms. Smith reserves the right to supplement and/or amend this report and the opinions expressed herein as additional information becomes available, and/or to perform additional testing and analysis and amend this report as needed based upon observations and findings related to ongoing testing.

Report Prepared by:

C L Smith

Cynthia L. Smith
President and Technical Manager

APPENDIX 1

Curriculum Vitae of Cynthia L. Smith

Paragon
POLYMER CONSULTANTS

Curriculum Vitae of Cynthia L. Smith

Cynthia L. Smith
President
Paragon Polymer Consulting, LLC
148 Lugnut Lane, Suite 201 ♦ Mooresville, NC 28117
♦ Telephone: (704) 728-5879 ♦ FAX: (704) 663-0073
csmith@paragonpolymer.com

EDUCATION

Bachelor of Science and Engineering, December 1993
Materials Science and Engineering
Arizona State University
GPA: 3.64 (graduated Magna Cum Laude)

EMPLOYMENT EXPERIENCE

PRESIDENT
Vanguard Material Sciences, LLC Oct 2013 to Present
Paragon Polymer Consulting, LLC July 2009 to Present
Currently providing forensic consulting for metals, polymers, and composites; failure analysis; investigative chemistry; material testing and analysis; warranty claims resolution; and expert testimony in litigation-related claims for manufacturers, attorneys, insurance companies, and engineers from various industries. Analyses include determination of the root cause of failure, evaluation of material integrity, and investigation to determine if a manufacturing defect, environmental degradation, atypical residual and/or applied stresses, or improper installation may have contributed to failure.

TECHNICAL MANAGER AND SR. MATERIALS ENGINEER
Metallurgical Technologies, Inc. Oct 2007 to Jun 2009
Managed and performed numerous analytical investigations to determine the root cause of failure in a wide variety of metallic and polymeric components. Analyses included evaluations of aerospace components, metal and polymer plumbing products (brass plumbing fittings, PEX tubing, stainless steel crimp rings, copper tubing, etc.), plastic and metallic dishwasher components, fire protection system components, corroded hog feeders, plastic oil filters, chemical-compatibility studies, paint and coating failures, and microbiologically influenced corrosion evaluations in metals and plastics. Provided expert testimony for litigation-related claims.

MANAGER OF MATERIAL ANALYSIS
Uponor North America ("Wirsbo") Jul 2002 to Oct 2007
Created and managed the Material Analysis Laboratory at Uponor North America. This was an engineering services laboratory dedicated to failure analysis of metals and extruded/injection molded polymers, investigative chemistry, process research and development, and materials engineering related to warranty claims resolution and new product development. Responsible for creation and management of the department, hands-on failure analysis and fracture interpretation, materials engineering support, design of experiments, on-site inspections, expert witnessing in litigation-related claims, and technical support for executive management, engineering, manufacturing, suppliers, installers, and end-use customers.

DIRECTOR OF FAILURE ANALYSIS/INVESTIGATIVE CHEMISTRY
Stork Twin City Testing Oct 2001 to Jul 2002
Managed the Failure Analysis and Investigative Chemistry Group at Stork Twin City Testing. Position included hands-on failure analysis as well as director-level management responsibilities (budgeting, new business development, client relations, employee growth and development, staffing, developing marketing strategies and marketing materials, etc.). Projects encompassed a wide range of products, materials (metals, plastics, and composite systems), and industries. Launched new investigative services related to microbiologically influenced corrosion.

METALLURGICAL FAILURE ANALYST
AlliedSignal Engines May 1993 to June1999
Conducted sophisticated failure analyses of numerous gas turbine engine components in a customer service environment as part of a self-managed, high-performance work team. Analyses required extensive fractography as well as the collection and evaluation of related chemical, mechanical, metallurgical, and system performance data. Interacted extensively with individuals from all levels of the organization, as well as with outside customers and representatives from governing agencies such as the Federal Aviation Administration and the National Transportation Safety Board. Prepared work instructions related to the ISO9001 certification process. Trained technicians and new-hires in technical procedures.

CIVIL ENGINEERING TECHNICIAN
US Army Corps of Engineers May 1991 to May 1993
Managed flood control studies in the state of Arizona. Included problem assessment, solution development, coordination of technical efforts, economic evaluation, and technical report writing. Commended for exceptional efforts in conducting an economic evaluation of a railroad culvert failure.

FAILURE ANALYST/METALLURGIST
Dominion Power Company Sept 1989 to Jan 1991
Conducted failure analyses of many diverse power generation equipment failures by collecting and evaluating related chemical, mechanical, metallurgical, and system performance data. Monitored cathodic protection levels, soil resistivities, and the performance of corrosion resistant coatings. Produced and presented numerous technical reports. *Cooperative Education Student position.*

RESEARCH ASSISTANT
NC State University Sept 1988 to May 1989
Contributed to research pertaining to the relationship between the surface chemistry and solar cell performance of $CuInSe_2$ photoelectrical semiconductors.

RESEARCH COLLABORATOR
Brookhaven National Laboratory June 1987 to Aug 1987
Conducted a comparative analysis of spectral response and temperature dependency of polymer photovoltaic cells to amorphous silicon and crystalline silicon photovoltaic cells.

SPECIFIC FAILURE ANALYSIS EXPERIENCE

Materials: polyethylene, polyester, nylon, PEX, polysulfone, polyphenylsulfone, polyacetyl, nylon, PVC, CPVC, ABS, polypropylene, polycarbonate, paints and coatings, titanium alloys, nickel-base superalloys, copper alloys, aluminum alloys, stainless steel alloys, cast iron, plain carbon steel, tool steel, single crystal materials, and others.

Industries: manufacturing, plumbing, aerospace, power generation/distribution, fire protection, construction, insurance, legal, polymer extrusion, polymer injection molding, chemical processing, consumer products, and others.

Processes: polymer oxidation and degradation, environmental stress cracking, fatigue, brittle and ductile overload, microbiologically influenced corrosion, stress corrosion cracking, hot corrosion/sulfidation, dealloying (i.e., dezincification), pitting corrosion, environmental degradation of polymers, coating failure analysis, water chemistry testing as it relates to corrosion of metals and environmental degradation of polymers, and others.

LICENSES AND CERTIFICATIONS

Certified trainer for *Managing Interpersonal Relationships* classes (1995).

PROFESSIONAL AFFILIATIONS

- Voting Member of ASTM International (Technical Committee F17 on Plastic Piping Systems)
- Member of the Society of Plastics Engineers (SPE)
- Member of ASM International (American Society for Materials)
- Past President of the Phoenix Chapter of ASM
- Past President of the Arizona State University Student Chapter of ASM

Ms. Smith has not authored any publications during the past ten years.

APPENDIX 2

Published Literature Considered

Published Literature Considered

ASSESSING MATERIAL PERFORMANCE IN CHLORINATED POTABLE WATER APPLICATIONS, P. Vibien, et al., Jana Laboratories Inc., Aurora, Ontario, Canada (undated)

Changes in Carbonyl Index and Average Molecular Weight on Embrittlement of Enhanced-Photodegradable Polyethylenes, A. L. Andrady, et al., Journal of Environmental Polymer Degradation, Vol. I, No. 3, 1993

CHARACTERIZING LONG-TERM PERFORMANCE OF PLASTIC PIPING MATERIALS IN POTABLE WATER APPLICATIONS, Sarah Chung, et al., Jana Laboratories Inc.
Aurora, Ontario, Canada, ANTEC 2008, 2423-2427

CHLORINE RESISTANCE TESTING OF CROSS-LINKED POLYETHYLENE PIPING MATERIALS, P. Vibien, et al., Jana Laboratories Inc., Aurora, ON (undated)

CHLORINE RESISTANCE TESTING OF UV EXPOSED PIPE, J. Couch, et al., Jana Laboratories Inc., Aurora, Ontario, Canada (undated)

Effect of chlorinated water on the oxidative resistance and the mechanical strength of polyethylene pipes, D. Castagnetti, et al., Polymer Testing 30 (2011) 277-285

EVALUATION METHODS FOR CROSSLINKED POLYETHYLENE PIPES FOR HOT WATER SUPPLY AND SPACE HEATING SYSTEMS, Hiroyuki Nishimura, et al., Energy Technology Laboratories (undated)

FAILURE ANALYSIS OF CROSS-LINKED POLYETHYLENE PIPE IN RESIDENTIAL PLUMBING AND HEATING SYSTEMS, Phillip A. Sharff, et al., Simpson Gumpertz & Heger Inc. (undated)

Field Failure Analysis: Pinhole Mode of Failure of Polyolefin Pipes, A. Caratus, et al., Fracture Mechanics & Materials Durability Laboratory, UIC, Chicago, IL, ANTEC 2007, 928-932

Interlaboratory reproducibility of standard accelerated aging methods for oxidation of UHMWPE, S.M. Kurtz, et al., Biomaterials 22 (2001) 1731-1737

Kinetics of chlorine-induced polyethylene degradation in water pipes, C. Devilliers, et al., Polymer Degradation and Stability 96 (2011) 1361-1368

Long term durability of crosslinked polyethylene tubing used in chlorinated hot water systems, Steven W. Bradley, et al., PLASTICS RUBBER AND COMPOSITES, MAY 1999

MODELLING MECHANISMS OF BRITTLE OXIDATIVE DEGRADATION TO ENSURE PLASTIC PIPE MATERIAL PERFORMANCE, S. Chung, et al., Jana Laboratories Inc., Aurora, ON Canada, ANTEC 2004, 2769-2773

THE BUILDING AND PLUMBING BULLETIN, NSF, Summer 2010

Interlaboratory studies to determine optimal analytical methods for measuring the oxidation index of UHMWPE, S.M. Kurtz, et al., Biomaterials 22 (2001) 2875-2881

Oxidative Degradation of High Density Polyethylene Pipes from Exposure to Drinking Water Disinfectants, Donald E. Duvall, et al., Engineering Systems Inc., Aurora, IL (presentation undated, report dated 12/18/09)

DESIGN GUIDE: Residential PEX Water Supply Plumbing Systems, Second Edition, Plastic Pipe and Fittings Association, et al. (undated)

STATEMENT A: Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants used in Treated Potable Water on Crosslinked Polyethylene (PEX) Plastics Pipe Institute, originally adopted January 2007, Revised July 9, 2013

Crosslinked Polyethylene (PEX) Pipe & Tubing TN-17/2013, Plastics Pipe Institute, February 2013

Nature of Hydrostatic Stress Rupture Curves TN-7/2005, Plastics Pipe Institute, June 2005

Chemical Resistance of Thermoplastics Piping Materials TR-19/2007, Plastics Pipe Institute, September 2007

EVALUATION METHODS FOR CROSSLINKED POLYETHYLENE PIPES FOR HOT WATER SUPPLY AND SPACE HEATING SYSTEMS, Hiroyuki Nishimura, et al., Energy Technology Laboratories (undated)

Plastic Failure Guide: Cause and Prevention, 2nd Edition, Myer Ezrin, Hanser Publications, 2013

Relationships between Oxidation-Reduction Potential, Oxidant, and pH in Drinking Water, Cheryl N. James, et al., University of Cincinnati, Department of Chemical Engineering, Cincinnati, OH, 2004

AN EXAMINATION OF THE RELATIVE IMPACT OF COMMON POTABLE WATER DISINFECTANTS (CHLORINE, CHLORAMINES AND CHLORINE DIOXIDE) ON PLASTIC PIPING SYSTEM COMPONENTS, Sarah Chung, et al., Jana Laboratories Inc., Aurora, Ontario, Canada, ANTEC 2007, 2940-2944

Surface embrittlement of polyethylene, Choi, Sunwoong, Ph.D. Illinois Institute of Technology, 1992

THE MECHANISMS OF CHLORINE DIOXIDE OXIDATION ON PLASTIC PIPING SYSTEMS, Sarah Chung, et al., Jana Laboratories Inc., Aurora, Ontario, Canada, ANTEC 2008, 2419-2422

APPENDIX 3

Fee Schedule of Cynthia L. Smith

Paragon
POLYMER CONSULTANTS

Fee Schedule for Cynthia L. Smith

January 1, 2017

Fee Schedule:

- Laboratory consulting services associated with testing and analysis of materials or components, preparation of test protocols, on-site inspection(s), and documentation of test results are invoiced at a rate of $225.00 per hour, plus expenses. All travel time and consulting time is billed in quarter hour increments, rounding to the nearest quarter hour.

- Litigation-related consulting services (document reviews, design reviews, depositions, expert testimony, transcript reviews, etc.) are invoiced at a rate of $325.00 per hour, plus expenses (if any). All travel time and consulting time is billed in quarter hour increments, rounding to the nearest quarter hour.

- Direct expenses for laboratory testing, purchase of applicable standards or test methods, travel, etc. (if required) are invoiced separately.

APPENDIX 4

History of Expert Testimony for Cynthia L. Smith

Since 2007, Cynthia L. Smith has testified as an expert in the following cases:

A. *Uponor, Inc. v. Unique Industrial Product Company*
United States District Court for the Southern District of Texas
Civil Action No. 07-2986
Plaintiff's Expert, Deposed: 2008

B. *Lennar Homes, Inc. v. Radiant Technologies, Inc., Zurich American Insurance Company, and Midtec, Inc.*
Superior Court of San Diego County California
Super. Ct. No. GIC865871
Defendant's Expert, Deposed: 2007

C. *Travelers Indemnity Company as subrogee of The Residences at Biltmore Condominium HOA, Inc. v. Diboco Fire Sprinklers, Inc. and Victaulic Company*
United States District Court for the Western District of North Carolina
Asheville Division
Case No.: 1:08-cv-00548-MR-DLH
Plaintiff's Expert, Deposed 2/23/2010

D. *Joel Thibodeaux v. Wellmate (Pentair Water Treatment Company of Ohio)*
United States District Court for the Eastern District of Louisiana
Court File No. 2:12-cv-1375
Plaintiff's Expert, Deposed: 8/6/2013, Trial Testimony: 6/01/2016

E. *Jackie Alford and Phyllis Alford vs Lowe's Home Center, Inc. and Lehigh Consumer Products, LLC*
United States District Court for the District of South Carolina
Civil Action No.: 8:13-cv-01787-GRA
Plaintiff's Expert, Deposed: 3/21/2014

F. *Viva Healthcare Packaging, Ltd., Viva Healthcare Packaging (HK) Ltd. And Viva Healthcare Packaging (USA) Inc., v. CLT Packaging USA, Inc. and Tuboplast Hispania*
United States District Court for the Western District of North Carolina
Charlotte Division
Case No.: 13-CV-00569 (MOC) (DSC)
Defendant's Expert, Deposed: 7/10/2014, Court Testimony: 11/12/2014, Deposed: 6/10/2016

G. *Anthony J. Parsons, Adam Stein, and Ellen Stein v. NIBCO, Inc.*
United States District Court, Eastern District of North Carolina
Western Division
Civil Action No.: 5:13-CVS-00744
Plaintiff's Expert, Deposed: 9/4/2014

H. *Jonathon Suarez v. Pro Trucking, LLC*
State of South Carolina in the Court of Common Pleas
County of Greenville, The Thirteenth Judicial Circuit
Civil Action No.: 2013-CP-23-2729
Plaintiff's Expert, Deposed: 10/29/2014

I. *Kerry Michelle Moloney and Robert R. Ingraham v. Michael James Corbi Individually and d/b/a All-Pro Plumbing, All Pro Plumbing, LLC, and All Pro Plumbing Contractors, LLC*
State of North Carolina
Superior Court Division
Civil Action No.: 12-CVS-01270
Plaintiff's Expert, Deposed: 11/21/2014

J. *HDR Constructors, Inc., v. Waste Connections, Inc., successor to R360 Environmental Solutions, Inc.*
American Arbitration Association
Construction Industry Tribunal – Houston, Texas
Case No. 70-158-Y-00707-13
Respondent's Expert, Arbitration Testimony: 12/4/2016

K. *Christianson Air Conditioning and Plumbing, LLC v. NIBCO, Inc., MRK Manufacturer's Sales, Inc., and Morrison Supply Company, LLC*
District Court of Travis County, Texas
261st Judicial District
Civil Action No.: D-1-GN-14-000962
Plaintiff's Expert, Deposed: 3/30/2016

APPENDIX 5

Water Chemistry Results

(produced in digital format)

APPENDIX 6

Stereomicroscope Images

(produced in digital format)

APPENDIX 7

Date Code Analysis

(produced in digital format)

APPENDIX 8

Dimensional Inspection Results for Outer Diameter

(produced in digital format)

APPENDIX 9

Non-Conforming NIBCO Pipe Dimensions

(produced in digital format)

APPENDIX 10

Scanning Electron Microscopy

(produced in digital format)

APPENDIX 11

FTIR Spectra

(produced in digital format)

APPENDIX 12

FTIR Radar Graphs

(produced in digital format)

APPENDIX 13

Oxidation Induction Time Data

(produced in digital format)

APPENDIX 14

Oxidation Induction Time Thermograms

(produced in digital format)

APPENDIX 15

Oxidation Induction Time Graphs

(produced in digital format)

APPENDIX 16

Chemical Analysis Results

(produced in digital format)